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TECHNOLOGY INVESTMENT STRATEGY ANNEX, COLLECTIVE PROTECTION FRONT END ANALYSIS AND MASTER PLAN REPORT

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14. ABSTRACT
The Chemical Biological (CB) Tech Base program funds 6.2 projects to investigate and develop technologies for CB Defense. The program consists of several business areas, one of which is Collective Protection (CP). The CP Business Area Manager (BAM) conducted a Front-end Analysis (FEA) to identify promising technologies for future applications. Candidate technologies were evaluated and ranked relative to performance, operational, and logistical factors. The FEA process identified several feasible technologies, and the CP BAM had to choose which technologies to invest in with a limited budget. The Decision Analysis Team created a Master Plan (MP) process to examine investment options and to develop an overall program funding strategy. Maturity, risk, and payoff were the major factors considered. The process enabled the BAM to construct several investment portfolios that reflected varying levels of risk and cost. The ultimate product from this process was a listing of "Best Buys," consisting of a combination of technologies at optimal funding levels; the "Best Buy" package will yield the highest benefit for a specified budget. This effort established a new methodology using cost analysis and resource allocation methods to develop investment strategies. This process is repeatable, defensible, and allows for justifiable investment decisions.

15. SUBJECT TERMS

Master Plan Methodology	Decision analysis	Investment portfolios
Cost analysis	Funding levels	Investment decisions
Resource Allocation	Maturity, risk, and payoff	

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EXECUTIVE SUMMARY

Objective

The Collective Protection (COLPRO) Business Area Manager (BAM) is continuously faced with investment decisions, i.e., deciding how much of his limited Tech Base funding should be invested in which technology R&D programs. The BAM needs a method to help him develop and examine alternative funding strategies for different technology thrust areas (e.g. Air Purification, Shelter Materials, and Critical Components) within the business area to determine which investment portfolio will provide the highest return.

Method and Approach

The Decision Analysis Team worked with the COLPRO BAM and subject matter experts (SMEs) to develop resource allocation models that help identify the combinations of technologies that offer the most efficient use of a finite budget. Three software packages were used to support the process—DPL™, EXCEL™, and EQUITY™.

Using DPL™ to create a decision tree model, each high potential technology was represented as a separate "investment decision", i.e., whether or not to fund a technology, and at what level. Strategy tables were then created to identify sets of technology investment decisions (Figure 1), design alternative investment strategies—no investment, low investment, moderate investment, or high investment (Figure 2), and evaluate them to determine the expected value of each strategy.

For each technology, a panel of SMEs estimated the costs of alternative investment levels, probabilities of success, technology benefit levels, and overall technology weights. The weights reflect each technology's relative importance, and are based on potential performance and current maturity levels.

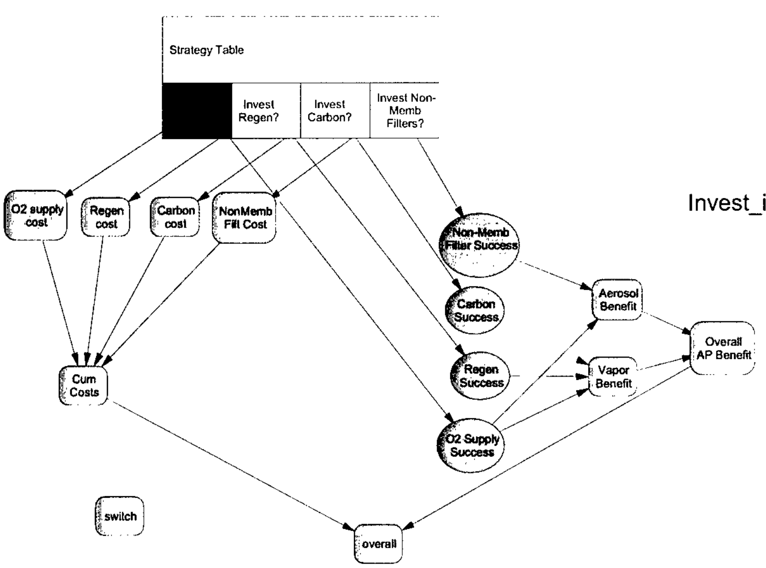

Figure 1. DPL Strategy Table

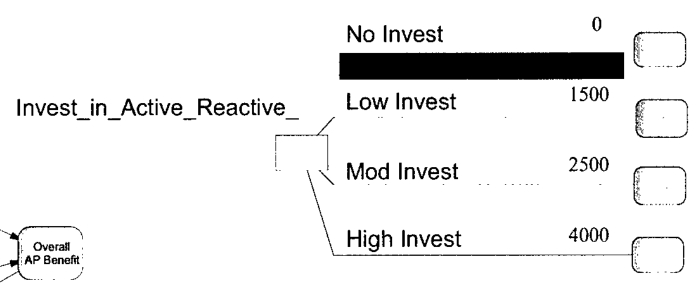

Figure 2. Alternative Investment Levels

These assessed measures were compiled into an EXCEL™ spreadsheet (Figure 3).

Technologies				Program Outcome Probability of Success (1)				Technology Weight (2)
				Minimal	Partial	Complete	Total Prob.	
Closures Seams and Seals	Investment Level ($000)	[illegible]	$3,000	0.50	0.30	0.20	1.00	26%
		[illegible]	$6,000	0.30	0.40	0.30	1.00	
		[illegible]	$11,000	0.10	0.30	0.60	1.00	
	Technology Benefit (3)			10	66	100		

Figure 3. Example Technology Program Estimates

Results/Products:

The decision tree models for each of the COLPRO technology thrust areas produce thousands of potential combinations of investment levels. EQUITY™ is a resource allocation software tool useful for examining all the possible combinations of the technology investments and finding those combinations that provide the most overall benefit for any given level of funding.

In EQUITY™, a Pareto Diagram is a graphical representation of all benefit-to-cost combinations (Figure 4). In this diagram, all the feasible combinations fall within the green-shaded area. The set of optimum investment strategies is represented in the diagram on the upper "frontier" of the diagram. These are the best strategies across a range of different investment funding levels, or costs. A "best value" investment strategy is located at the "knee" of the frontier curve. Beyond the knee, additional funding provides diminishing returns.

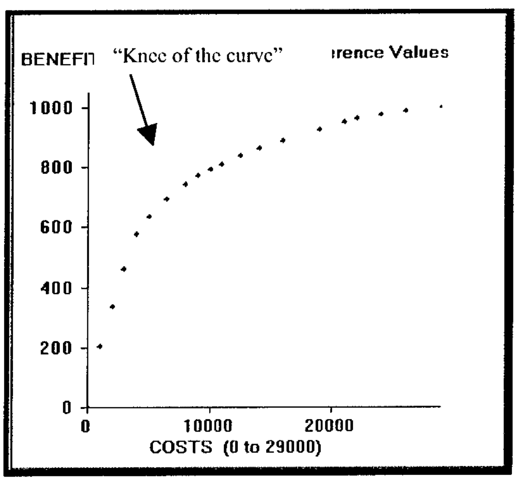

Figure 4. Example EQUITY Pareto Diagram

The priority order for funding the technologies and the funding levels are listed in an "Order of Buy", showing the incremental and cumulative costs and benefits for the technologies (Figure 5). From this model and assessment exercise, a portfolio of technology investments that provides the best use of limited funding can be determined.

Order of Buy

	TECH		LEVEL		COSTS INC	COSTS CUM	BENEFITS INC	BENEFITS CUM
#0	1	Heterog	1	None	0	0	0	0
#0	2	Homog	1	None	0	0	0	0
#0	3	Multil	1	None	0	0	0	0
#0	4	Semiperm	1	None	0	0	0	0
#0	5	SelecPerm	1	None	0	0	0	0
#0	6	HiSurTen	1	None	0	0	0	0
#0	7	ActReact	1	None	0	0	0	0
#1	3	Multil	2	Low	1000	1000	163	163
#2	1	Heterog	2	Low	1000	2000	114	277
#3	4	Semiperm	2	Low	1000	3000	100	376
#4	5	SelecPerm	2	Low	1000	4000	64	441
#5	2	Homog	2	Low	1000	5000	49	489
#6	6	HiSurTen	2	Low	1500	6500	36	525
#7	7	ActReact	2	Low	1500	8000	34	559
#8	5	SelecPerm	3	Mod	1000	9000	16	576
#9	3	Multil	3	Mod	1000	10000	15	590
*10	3	Multil	4	High	1000	11000	15	605
#11	6	HiSurTen	3	Mod	1500	12500	20	625
#12	1	Heterog	4	High	2000	14500	23	648
#13	7	ActReact	3	Mod	1500	16000	15	663
#14	4	Semiperm	3	Mod	1000	17000	9	672
#15	7	ActReact	4	High	3000	20000	23	695
#16	5	SelecPerm	4	High	2000	22000	13	708
#17	4	Semiperm	4	High	2000	24000	11	719
#18	2	Homog	4	High	2000	26000	10	729
#19	6	HiSurTen	4	High	3000	29000	9	738

Figure 5. Example Order of Buy

The BAM developed three initial investment models—one for each of his technology thrust areas. Two Working Groups comprised of COLPRO SMEs attempted to validate the best value strategies resulting from the models by independently developing model parameters. The Working Groups restructured the models and provided a number of assessments that were significantly different from the BAM. The resulting Working Group models for Air Purification and Shelters were not able to validate the best value strategies from the initial models.

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PREFACE

The work described in this report was started in August 2002 and completed in September 2003.

This report was prepared in response to a request from the Collective Protection Business Area Manager (COLPRO BAM) to extend the CP Business Area Master Planning Model developed during the COLPRO Front End Analysis and Master Planning process in 2001. It is an annex to the previously published FEA/MP report.

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TECHNOLOGY INVESTMENT STRATEGY ANNEX, COLLECTIVE PROTECTION FRONT END ANALYSIS AND MASTER PLAN REPORT

1. OVERVIEW

The Chemical Biological Collective Protection (CB COLPRO) Master Plan Summary, dated February 2002, stated: "Key objectives of the Master Plan were to determine areas of technical emphasis within the COLPRO business area, examine funding strategy alternatives, and determine the combinations of technologies that can provide the most effective use of a finite budget. These combinations are represented by variables in a software model.... The model allows the Business Area Manager (BAM) to consider a number of strategy variations to test the robustness of the investment strategy for each technology category. These exercises can demonstrate where it may be desirable to make less risky investments and accept more modest expected returns."

This Technology Investment Strategy Annex provides conclusions based on these exercises and is the final step in the COLPRO Front End Analysis (CP FEA) and Master Planning (CP MP) processes for 2001-2002. The Technology Investment Strategies were developed in a series of meetings between the CB COLPRO BAM and subject matter experts (SME) from January 2002 to August 2002.

The CP FEA process consisted of a technical assessment on all viable *Air Purification* and *Shelter Materials and Treatments* technologies. The result of the assessment was a ranking of the technologies relative to five application areas. The rankings were based on how well each technology performed against 14 criteria that were oriented towards Efficacy, Operational, Logistical, and Safety, Health, and Environment considerations. These results indicated each technology's potential at satisfying the set of user requirements as described in the various program Operational Requirements Documents (ORD).

The CP FEA results and technology rankings were used to generate a set of "high potential" technologies. The CP MP process then evaluated these select technologies against other considerations, such as maturity and data gaps, to determine their potential to transition into viable products. The first product of this process was the identification of the technologies that will be emphasized in the Tech Base Program, and when they may be available to transition into acquisition programs. A second product of the process was a strategic resource allocation model that would help the BAM determine how to invest available funding in the COLPRO area, both at the technology level and at higher, programmatic levels. The CP Master Plan process involves four steps:

1. Define the COLPRO business area program framework;
2. Assess COLPRO high potential technologies, in terms of: maturity and data gaps/limitations, technology program/research activities, resource profiles, and technical risk;
3. Prioritize high potential technologies and establish transition timeframes;
4. Develop planning models and examine alternative program strategies.

The first three steps were documented in Section 8 of the Collective Protection Front End Analysis and Master Plan Report, dated March 2002. The final step involves determining areas of emphasis within the COLPRO Business Area. This includes determining investment priorities within the technology thrust areas, the technology categories, and between the various technologies themselves.

Although the technologies were prioritized in the CP MP, program resources necessary to fund 6.2 development for all the high priority technologies are not likely to be available. The objective of the investment strategy exercises was to examine alternative funding strategies and determine the mix of technologies that can provide the most effective use of limited dollars. A key assumption was that a mix of investments in a range of high value, but potentially redundant technology categories, would be a better investment strategy than investing solely in one or two categories. In addition, technologies that potentially contribute to more than one acquisition program or application area would be more cost-effective investments.

To accomplish this final objective, an analytical framework was constructed during the CP MP process. The framework is a decision tree model based on the software package DPL™ (Applied Decision Analysis, LLC). The decision tree let the BAM choose any set of technology investment decisions that, together, comprise an investment strategy, and shows expected benefits and costs resulting from the strategy. An advantage of the decision tree is the ability to incorporate uncertainty by examining various probabilities of success. Sensitivity analysis can also be performed to see how varied inputs, such as expected project costs, affect the outcomes.

The process used to develop the DPL™ decision tree model is described in Section 8.5 of the Collective Protection Front End Analysis and Master Plan Report, dated March 2002. The resulting decision tree model was used to analyze a small number of investment strategies for the BAM. That model showed that for both AP and Shelters, the expected benefits from technology investment reached a point of diminishing return. That "knee of the curve" suggested that a "best value" strategy existed for each technology thrust area.

However, the decision tree model was not able to help the BAM to easily identify the best strategy to recommend among the thousands of potential combinations of funding levels for each technology thrust area. For this answer, resource allocation models were built based on the decision tree framework.

The CB COLPRO BAM met with members of the Decision Analysis Team (DAT) in January 2002 to develop Technology Investment Strategies for each of the three Technology Thrust Areas: Air Purification, Shelter Materials and Treatments, and Critical Components. These strategies were developed using "initial" resource allocation models that extended the decision trees discussed in the Executive Summary for assessing the various investment priorities and allowed the BAM to explore and optimize technology investments for any given level of resources. These initial models were later revised by Working Groups consisting of the BAM and selected SMEs.

The resource allocation models were developed using Microsoft EXCEL™ and the EQUITY™ software package (Enterprise LSE, Ltd.). EQUITY™ is a commercial modeling tool used for a wide variety of investment planning applications in government and industry. It uses the marginal benefit-to-cost ratio of each investment option to create an ordered list of investments where the priority order of investment choices does not change if the resources increase or decrease. The software allowed the BAM and DAT to meet the study objective of examining alternative funding strategies to determine the combination of technologies that would efficiently use limited funds.

2. TECHNOLOGY INVESTMENT STRATEGIES

2.1 Elements of the Strategy Models.

There are four major elements to an EQUITY™ investment strategy model: 1) the structure of investment areas and levels, 2) expected payoffs, or relative returns on investment levels, 3) probabilities of each potential outcome, and 4) priorities, or importance weights, among the various investment areas.

2.1.1 Structure.

The basic structure of the strategy model resembles a matrix. The technology investment categories are listed down the left-hand side of the matrix, and the potential levels of investment are listed across the top (Figure 1).

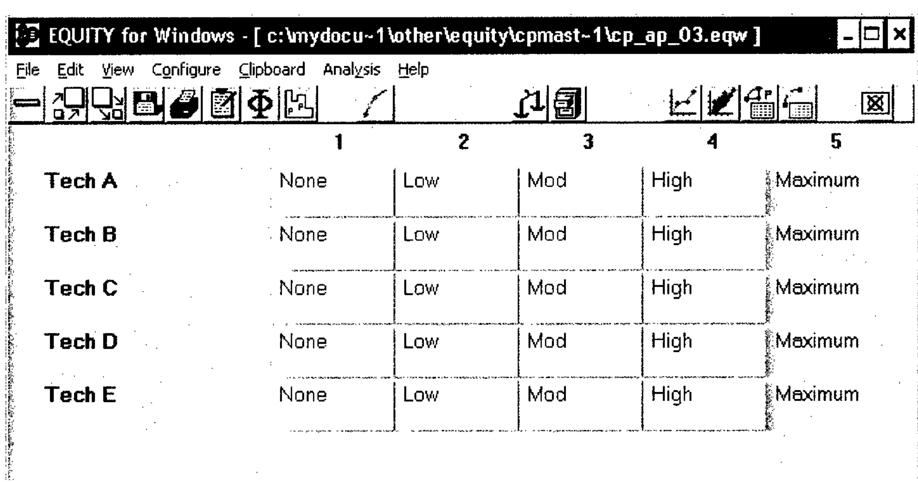


Figure 1. Technology Investment Strategy Model

The potential levels of investment, or the amount of resources spent, increase going from left to right. A "None" level (Level 1) is included to show that it is feasible not to invest in a technology category at all. A "Maximum" level of investment (Level 5) is included to show that there is a theoretical amount of resources that could mitigate all risk in a technology category and guarantee success, but it would be prohibitively expensive. A Moderate level of

investment was developed for each technology category based on the "nominal" or baseline cost estimates from the Master Plan. Increasing or decreasing the baseline levels, generally by 50% each way, also developed Low and High levels of investment.

2.1.2 Payoffs.

The expected results, or payoffs, from a technology investment are the next elements of the model. The initial models used three potential outcomes, defined as:

- Minimal Success: The research goals are not achieved, but there may be some residual contribution to the overall program;
- Partial Success: Many program objectives are achieved, such that the benefits achieved are somewhat more than halfway between the Minimal and Complete levels;
- Complete Success: All, or nearly all, program objectives are achieved.

In the models, each potential outcome has an expected relative benefit to the program. A relative benefit score of 100 is assigned to Complete Success. A relative benefit of 0 would result from no investment in the technology. The Minimal and Partial results represent the relative value of intermediate degree of success outcomes on the 0-100 interval scale.

For the initial models, the BAM assessed the relative values shown below in Table 1.

Table 1. Initial Model Payoffs

Complete Success	100
Partial Success	55
Minimal Success	10
No Success	0

The BAM assumed that relatively low value would result from any development effort that only had minimal success—about 10% of the total value of a completely successful effort—and a partial success would achieve somewhat more than 50% of the total possible value. With these assessments, the BAM expressed a neutral "risk preference" toward project success in that, in his judgment, increases in project value are commensurate with increases in degree of success.

2.1.3 Probabilities.

The BAM assumed that the probability of each potential outcome in the previous section would vary depending on the amount of resources invested. In other words, he would be able to increase the chances of success by investing more resources in a technology category. The BAM developed initial models with four feasible levels of investment—None, Low,

Moderate, and High—and assessed the probabilities of success across the outcomes using a matrix like the one shown below (Table 2).

Table 2. Example of Probabilities of Success

	Program Outcome Probability of Success		
Investment Level	**Minimal**	**Partial**	**Complete**
Low	.5	.4	.1
Moderate	.2	.6	.2
High	.1	.5	.4

The probabilities along each row in the table above must sum to 1.0. An investment level of "None" always results in No Success. In contrast to the single set of payoff values that the BAM applied to all technology categories (Table 1), the BAM assessed a different pattern of probabilities for each technology category. These assessed probability sets are shown in Tables 3, 4, and 5. Although the BAM assessed equivalent payoff values for each technical category, the probabilities assigned by the BAM varied for each technical category.

Table 3. Air Purification Initial Model Inputs

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Probability Adjusted Benefits	Technology Weight
O2 Supply	Investment Level ($000)	Low	$4,500	0.80	0.15	0.05	1.00	21.25	21%
		Moderate	$9,000	0.50	0.30	0.20	1.00	41.50	
		High	$13,500	0.30	0.40	0.30	1.00	55.00	
	Technology Benefit			10	55	100			
CatOx	Investment Level ($000)	Low	$5,000	0.60	0.30	0.10	1.00	32.50	19%
		Moderate	$10,000	0.40	0.45	0.15	1.00	43.75	
		High	$15,000	0.35	0.40	0.25	1.00	50.50	
	Technology Benefit			10	55	100			
Regen	Investment Level ($000)	Low	$3,850	0.75	0.20	0.05	1.00	23.50	17%
		Moderate	$7,700	0.40	0.45	0.15	1.00	43.75	
		High	$11,550	0.30	0.40	0.30	1.00	55.00	
	Technology Benefit			10	55	100			
Noncarbon Materials	Investment Level ($000)	Low	$1,750	0.70	0.25	0.05	1.00	25.75	8%
		Moderate	$3,500	0.45	0.40	0.15	1.00	41.50	
		High	$5,250	0.30	0.40	0.30	1.00	55.00	
	Technology Benefit			10	55	100			
Nonmembrane Filters	Investment Level ($000)	Low	$1,500	0.70	0.25	0.05	1.00	25.75	8%
		Moderate	$3,000	0.20	0.50	0.30	1.00	59.50	
		High	$4,500	0.10	0.30	0.60	1.00	77.50	
	Technology Benefit			10	55	100			
Engineered Composites	Investment Level ($000)	Low	$1,800	0.55	0.40	0.05	1.00	32.50	6%
		Moderate	$3,600	0.25	0.50	0.25	1.00	55.00	
		High	$5,400	0.15	0.45	0.40	1.00	66.25	
	Technology Benefit			10	55	100			
Fiber Filter Treatments	Investment Level ($000)	Low	$1,500	0.60	0.35	0.05	1.00	30.25	8%
		Moderate	$3,000	0.25	0.50	0.25	1.00	55.00	
		High	$4,500	0.20	0.35	0.45	1.00	66.25	
	Technology Benefit			10	55	100			
Activated Carbon	Investment Level ($000)	Low	$1,500	0.50	0.35	0.15	1.00	39.25	13%
		Moderate	$3,000	0.25	0.50	0.25	1.00	55.00	
		High	$4,500	0.15	0.40	0.45	1.00	68.50	
	Technology Benefit			10	55	100			

Table 4. Shelter Materials Initial Model Inputs

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Probability Adjusted Benefits	Technology Weight
Impermeable Barrier Materials									
Heterogeneous	Investment Level ($000)	Low	$1,000	0.15	0.45	0.40	1.00	66.25	16%
		Moderate	$2,000	0.10	0.40	0.50	1.00	73.00	
		High	$3,000	0.05	0.30	0.65	1.00	82.00	
	Technology Benefit			10	55	100			
Homogeneous	Investment Level ($000)	Low	$1,000	0.15	0.50	0.35	1.00	64.00	7%
		Moderate	$2,000	0.10	0.45	0.45	1.00	70.75	
		High	$3,000	0.05	0.35	0.60	1.00	79.75	
	Technology Benefit			10	55	100			
Multilayer	Investment Level ($000)	Low	$1,000	0.15	0.55	0.30	1.00	61.75	24%
		Moderate	$2,000	0.10	0.50	0.40	1.00	68.50	
		High	$3,000	0.05	0.45	0.50	1.00	75.25	
	Technology Benefit			10	55	100			
Vapor Permeable									
Semipermeable	Investment Level ($000)	Low	$1,000	0.15	0.45	0.40	1.00	66.25	14%
		Moderate	$2,000	0.10	0.40	0.50	1.00	73.00	
		High	$4,000	0.05	0.30	0.65	1.00	82.00	
	Technology Benefit			10	55	100			
Selectively Permeable	Investment Level ($000)	Low	$1,000	0.60	0.30	0.10	1.00	32.50	18%
		Moderate	$2,000	0.50	0.30	0.20	1.00	41.50	
		High	$4,000	0.40	0.35	0.25	1.00	48.25	
	Technology Benefit			10	55	100			
Material Treatments									
High Surface Tension	Investment Level ($000)	Low	$1,500	0.50	0.45	0.05	1.00	34.75	9%
		Moderate	$3,000	0.20	0.60	0.20	1.00	55.00	
		High	$6,000	0.05	0.70	0.25	1.00	64.00	
	Technology Benefit			10	55	100			
Active/Reactive	Investment Level ($000)	Low	$1,500	0.70	0.25	0.05	1.00	25.75	12%
		Moderate	$3,000	0.50	0.40	0.10	1.00	37.00	
		High	$6,000	0.25	0.50	0.25	1.00	55.00	
	Technology Benefit			10	55	100			

2.1.4 Priorities.

The final model element—priorities—is a relative weight on the technology categories that indicates the importance, or impact on the Business Area, of transitioning each one. While the value of success for each technology category was the same, some technologies, if successfully transitioned, would be preferred to other technologies. Therefore the BAM assigned a higher weight to the 0-100 scales of higher priority technologies.

The BAM used a combination of techniques to prioritize the categories in each of the three technology thrust areas, including an ordinal ranking technique, a pairwise comparison technique, and an anchoring and adjusting technique. In the ordinal ranking technique, called Simplified Multi-Attribute Rating Technique—Ranking (SMARTER), the BAM assessed weights by listing the rank order of importance of each technology category. Decision support software (Logical Decisions for Windows™) uses the importance ordering to compute a set of implied weights. The set of weights represents a center of mass of all the possible sets of weights consistent with the ordering using a "centroid" algorithm.

Table 5. Critical Components Initial Model Inputs

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Probability Adjusted Benefits	Technology Weight
Closures Seams and Seals	Investment Level ($000)	Low	$3,000	0.50	0.30	0.20	1.00	41.50	26%
		Moderate	$6,000	0.30	0.40	0.30	1.00	55.00	
		High	$11,000	0.10	0.30	0.60	1.00	77.50	
	Technology Benefit			10	55	100			
Airbeam	Investment Level ($000)	Low	$1,000	0.30	0.40	0.30	1.00	55.00	13%
		Moderate	$2,500	0.20	0.40	0.40	1.00	64.00	
		High	$4,000	0.10	0.40	0.50	1.00	73.00	
	Technology Benefit			10	55	100			
Tension Frame Fabric	Investment Level ($000)	Low	$500	0.55	0.30	0.15	1.00	37.00	3%
		Moderate	$1,000	0.40	0.35	0.25	1.00	48.25	
		High	$2,000	0.25	0.40	0.35	1.00	59.50	
	Technology Benefit			10	55	100			
Composite Frame Hinge	Investment Level ($000)	Low	$1,000	0.50	0.40	0.10	1.00	37.00	7%
		Moderate	$2,000	0.40	0.40	0.20	1.00	46.00	
		High	$3,000	0.30	0.40	0.30	1.00	55.00	
	Technology Benefit			10	55	100			
Threat Mitig Methods	Investment Level ($000)	Low	$1,000	0.40	0.30	0.30	1.00	50.50	10%
		Moderate	$3,000	0.15	0.30	0.55	1.00	73.00	
		High	$5,000	0.05	0.25	0.70	1.00	84.25	
	Technology Benefit			10	55	100			
Airlocks/ Barriers/Doors	Investment Level ($000)	Low	$1,000	0.45	0.35	0.20	1.00	43.75	19%
		Moderate	$3,000	0.30	0.30	0.40	1.00	59.50	
		High	$6,000	0.10	0.20	0.70	1.00	82.00	
	Technology Benefit			10	55	100			
Integrated Power ECU	Investment Level ($000)	Low	$1,000	0.55	0.30	0.15	1.00	37.00	16%
		Moderate	$3,000	0.30	0.35	0.35	1.00	57.25	
		High	$6,000	0.20	0.40	0.40	1.00	64.00	
	Technology Benefit			10	55	100			
Energy Eff Materials		Low	$1,000	0.6	0.3	0.1	1.00	32.50	6%
		Moderate	$3,000	0.4	0.3	0.3	1.00	50.50	
		High	$6,000	0.3	0.3	0.4	1.00	59.50	
	Technology Benefit			10	55	100			

In the pairwise comparison technique, called the Analytic Hierarchy Process (AHP), the BAM defined the weights by assessing ratios of the technology category importance—an importance ratio for each possible pair. In the AHP method, an approach based on linear algebra is used to compute a "best fit" set of weights based on the ratios entered.

In the anchoring and adjusting technique, called Simplified Multi-Attribute Rating Technique (SMART), the BAM defined the weights by entering the relative importances in the form of "swing weights". Swing weights describe the relative importance of "swinging" a technology from its least preferred to its most preferred level. He assigned a weight of 100 to the technology that is most important to swing to its most preferred level. He then assigned lower weights to the other technologies based on the relative importance of swinging them vs. the most important technology. The assessed weights are shown in Tables 3, 4, and 5 in the right-most column. The BAM used the weights computed by Logical Decisions for Windows™; each method refined the weights computed by the previous method.

2.2 Initial Air Purification Technology Investment Model.

The first of the three initial models was developed for the Air Purification technology thrust area. The CP FEA identified eight high potential technology categories and the Master Plan Report provides detailed descriptions of them. The model inputs are shown in Table 3. The numbers in the Probability Adjusted Benefits (PAB) column were obtained by multiplying the Program Outcome Probability of Success for the Minimal, Partial, and Complete levels by the respective Technology Benefit levels and then by summing all of the products for each of the investment levels. For example, to calculate the PAB for the Low Investment level of O2 Supply (21.25) one would do the following: (0.80*10) + (0.15*55) + (0.05*100).

Each technology category was treated as a separate investment area (row) within the model (Figure 2). For each potential investment level along a row, the cumulative costs and probability-adjusted benefits were assigned (from Table 3).

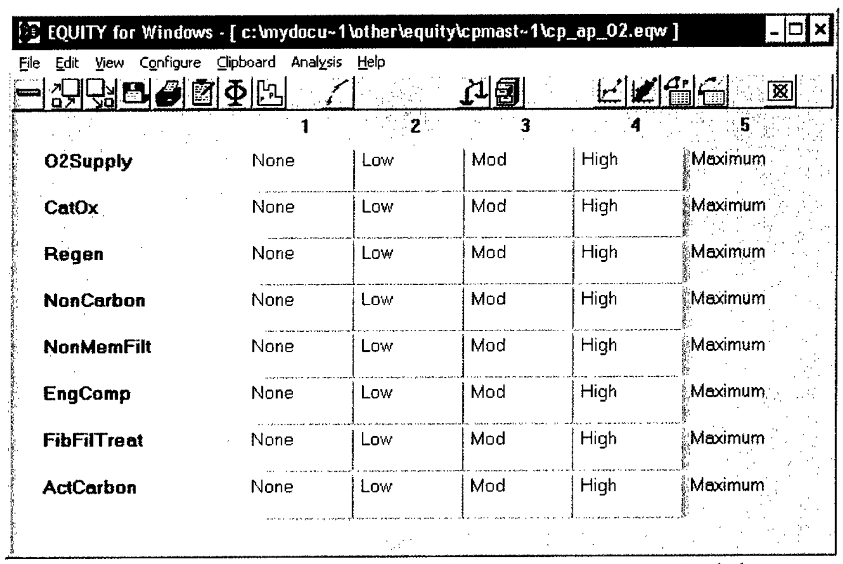


Figure 2. AP Initial Technology Investment Model

The model produces a Pareto diagram of all possible combinations of funding levels (390,625) EQUITY normalizes all benefits in a model so that the total possible is always a maximum of 1000 relative benefit points (Figure 3). However, even if the highest investment was made on all technologies (total of $64.2M) the BAM could not expect to achieve more than about 60% of the maximum benefit because of uncertainty about the success of the development efforts (593 out of 1000 points).

The green shaded area at the top of the diagram shows where these "infeasible" strategies lie. Infeasible strategies include at least one maximum level (Level 5), which assumes a 100% guaranteed complete success. The BAM did not consider this possibility to be feasible. The set of optimum frontier strategies, therefore, lies along the top edge of the yellow shaded area of feasible strategies.

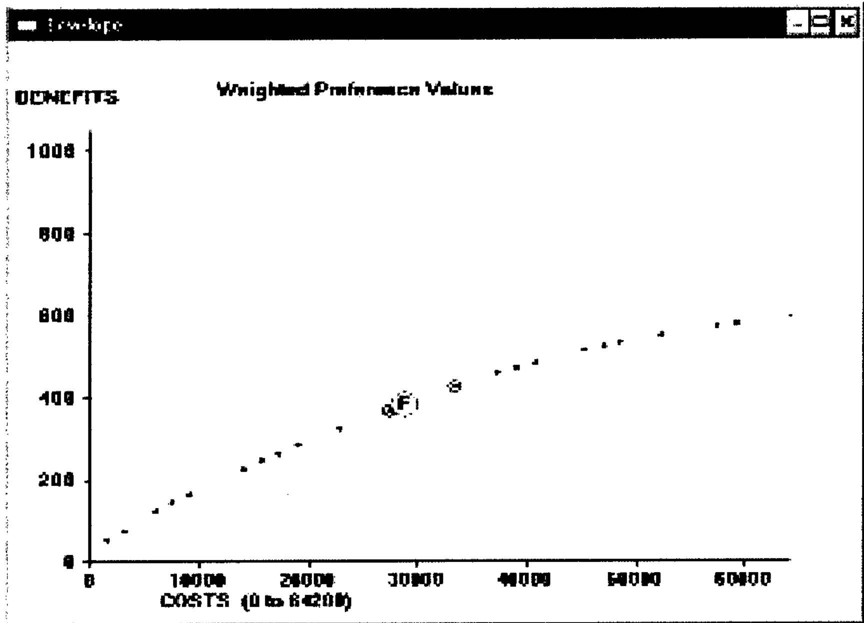


Figure 3. AP Pareto Diagram

Because the frontier curve is quite smooth, there is no "knee" and so it is not clear where the "best value" strategy lies. The "F" point along the frontier shows a typical best value strategy, where for a little less than 50% of the total cost, or $28.9 M, the program could achieve 382 points, or 64% of the feasible benefit. This suggested best value strategy, called the Frontier Package, is shown in Figure 4.

Frontier package

Frontier Pack #12 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	O2Supply	> 2 Low	4500	4500	45	45
2	CatOx	2 Low	5000	5000	62	62
3	Regen	2 Low	3850	3850	40	40
4	NonCarbon	2 Low	1750	1750	21	21
5	NonMemFilt	< 4 High	4500	4500	62	62
6	EngComp	2 Low	1800	1800	20	20
7	FibFilTreat	3 Mod	3000	3000	44	44
8	ActCarbon	4 High	4500	4500	89	89
Frontier package			28900	28900	382	382
Next Package #13			33400	33400	424	424
Previous Pack #11			27400	27400	367	367

Figure 4. AP Best Value Strategy

For each technology category, the recommended level of investment is shown in the LEVEL column. The RED arrow indicates the level that would be increased next if additional funds were invested (the next "buy"). The RED Next Package #13 shows the total cost and benefit of that "next" strategy. The BLUE arrow indicates the level that would be reduced next if funds were cut (the next "sell"). The BLUE Previous Package #11 shows the total cost and benefit of that "previous" strategy.

The COSTS and BENEFITS columns show the costs and benefits for each technology category at the recommended levels. The Total columns are the same as the Cost and Benefit columns because there are only one type of cost and one type of benefit in the model.

The complete Order of Buy is shown in Figure 5. This is the investment list that the BAM should follow in order to maximize the value of his investments at any cumulative level of funding. The best value strategy is shown at increment #12.

Order of Buy

	Order of Buy			COSTS		BENEFITS	
	TECH		LEVEL	INC	CUM	INC	CUM
#0	1 -	O2Supply	1 None	0	0	0	0
#0	2 -	CatOx	1 None	0	0	0	0
#0	3 -	Regen	1 None	0	0	0	0
#0	4 -	NonCarbon	1 None	0	0	0	0
#0	5 -	NonMemFilt	1 None	0	0	0	0
#0	6 -	EngComp	1 None	0	0	0	0
#0	7 -	FibFilTreat	1 None	0	0	0	0
#0	8 -	ActCarbon	1 None	0	0	0	0
#1	8 -	ActCarbon	2 Low	1500	1500	51	51
#2	7 -	FibFilTreat	2 Low	1500	3000	24	75
#3	5 -	NonMemFilt	3 Mod	3000	6000	48	123
#4	8 -	ActCarbon	3 Mod	1500	7500	20	143
#5	7 -	FibFilTreat	3 Mod	1500	9000	20	163
#6	2 -	CatOx	2 Low	5000	14000	62	225
#7	4 -	NonCarbon	2 Low	1750	15750	21	245
#8	8 -	ActCarbon	4 High	1500	17250	18	263
#9	6 -	EngComp	2 Low	1800	19050	20	283
#10	3 -	Regen	2 Low	3850	22900	40	322
#11	1 -	O2Supply	2 Low	4500	27400	45	367
#12	5 -	NonMemFilt	4 High	1500	28900	14	382
#13	1 -	O2Supply	3 Mod	4500	33400	42	424
#14	3 -	Regen	3 Mod	3850	37250	35	459
#15	6 -	EngComp	3 Mod	1800	39050	14	472
#16	4 -	NonCarbon	3 Mod	1750	40800	13	485
#17	1 -	O2Supply	4 High	4500	45300	28	513
#18	4 -	NonCarbon	4 High	1750	47050	11	524
#19	7 -	FibFilTreat	4 High	1500	48550	9	533
#20	3 -	Regen	4 High	3850	52400	19	552
#21	2 -	CatOx	3 Mod	5000	57400	21	573
#22	6 -	EngComp	4 High	1800	59200	7	580
#23	2 -	CatOx	4 High	5000	64200	13	593

Figure 5. AP Initial Order of Buy

2.3 Initial Shelter Materials and Treatments Technology Investment Model.

The second model was developed for the Shelter Materials and Treatments technology thrust area. The CP FEA identified seven high potential technologies in three technology categories (Table 4).

Each technology was treated as a separate investment area (row) within the model (Figure 6). For each potential investment level along a row, the cumulative costs and probability-adjusted benefits were assigned (from Table 4).

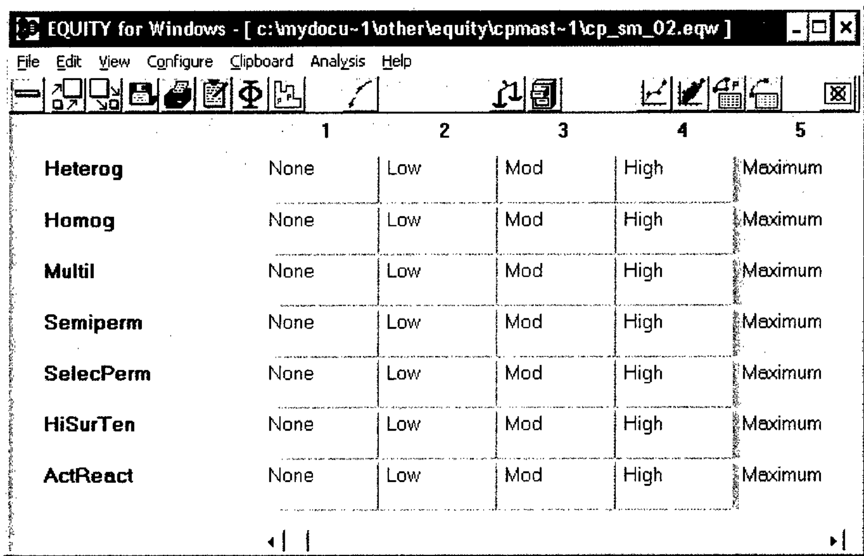


Figure 6. SM Technology Investment Model

The model produces a Pareto diagram of all possible combinations of funding levels with a maximum of 1000 relative benefit points (Figure 7). However, even if the highest investment was made on all technologies (total of $29 M) the BAM could not expect to achieve more than about 70% of the maximum benefit because of uncertainty about the success of the development efforts (693 out of 1000 points).

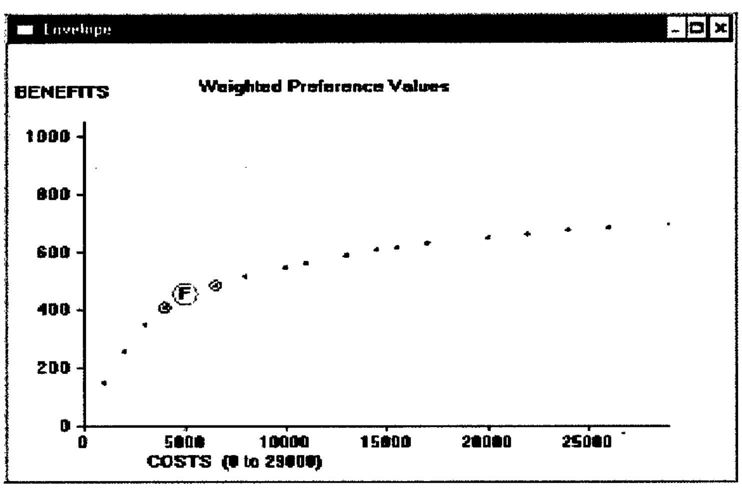


Figure 7. SM Pareto Diagram

The green shaded area at the top of the diagram shows where these "infeasible" strategies lie. (See the previous section for an explanation of infeasible strategies.) The set of optimum frontier strategies, therefore, lies along the top edge of the yellow shaded area of feasible strategies.

In this technology thrust area, there appears to be a clear "knee" on the frontier curve. The "F" point along the frontier shows a best value strategy, where for a little less than 20% of the total cost, or $5 M, the program could achieve 451 points, or 65% of the feasible benefit. This suggested best value strategy is shown in Figure 8.

Frontier package

Frontier Pack #5 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	Heterog	2 Low	1000	1000	106	106
2	Homog	< 2 Low	1000	1000	45	45
3	Multil	2 Low	1000	1000	148	148
4	Semiperm	2 Low	1000	1000	93	93
5	SelecPerm	2 Low	1000	1000	59	59
6	HiSurTen	> 1 None	0	0	0	0
7	ActReact	1 None	0	0	0	0
Frontier package			5000	5000	451	451
Next Package #6			6500	6500	482	482
Previous Pack #4			4000	4000	406	406

Figure 8. SM Best Value Strategy

For each technology category, the recommended level of investment is shown in the LEVEL column. The RED arrow indicates the level that would be increased next if additional funds were invested (the next "buy"). The RED Next Package #6 shows the total cost and benefit of that "next" strategy. The BLUE arrow indicates the level that would be reduced next if funds were cut (the next "sell"). The BLUE Previous Package #4 shows the total cost and benefit of that "previous" strategy.

The COSTS and BENEFITS columns show the costs and benefits for each technology category at the recommended levels. The Total columns are the same as the Cost and Benefit columns because there are only one type of cost and one type of benefit in the model.

The complete Order of Buy for Shelter Materials is shown in Figure 9. This is the investment list that the BAM should follow in order to maximize the value of his investments at any cumulative level of funding. The best value strategy is shown at increment #5.

			Order of Buy		COSTS		BENEFITS	
	TECH		LEVEL		INC	CUM	INC	CUM
#0	1 -	Heterog	1	None	0	0	0	0
#0	2 -	Homog	1	None	0	0	0	0
#0	3 -	Multil	1	None	0	0	0	0
#0	4 -	Semiperm	1	None	0	0	0	0
#0	5 -	SelecPerm	1	None	0	0	0	0
#0	6 -	HiSurTen	1	None	0	0	0	0
#0	7 -	ActReact	1	None	0	0	0	0
#1	3 -	Multil	2	Low	1000	1000	148	148
#2	1 -	Heterog	2	Low	1000	2000	106	254
#3	4 -	Semiperm	2	Low	1000	3000	93	347
#4	5 -	SelecPerm	2	Low	1000	4000	59	406
#5	2 -	Homog	2	Low	1000	5000	45	451
#6	6 -	HiSurTen	2	Low	1500	6500	31	482
#7	7 -	ActReact	2	Low	1500	8000	31	513
#8	3 -	Multil	4	High	2000	10000	32	545
*9	5 -	SelecPerm	3	Mod	1000	11000	16	561
#10	1 -	Heterog	4	High	2000	13000	25	587
#11	6 -	HiSurTen	3	Mod	1500	14500	18	605
#12	4 -	Semiperm	3	Mod	1000	15500	9	614
#13	7 -	ActReact	3	Mod	1500	17000	13	628
#14	7 -	ActReact	4	High	3000	20000	22	649
#15	4 -	Semiperm	4	High	2000	22000	13	662
#16	5 -	SelecPerm	4	High	2000	24000	12	674
#17	2 -	Homog	4	High	2000	26000	11	685
#18	6 -	HiSurTen	4	High	3000	29000	8	693

Figure 9. SM Order of Buy

2.4 Initial Critical Components Technology Investment Model.

The third initial model was developed for the Critical Components technology thrust area. The CP FEA identified 8 high potential technology categories (Table 5).

Each technology category was treated as a separate investment area (row) within the model (Figure 10). For each potential investment level along a row, the cumulative costs and probability-adjusted benefits were assigned (from Table 5).

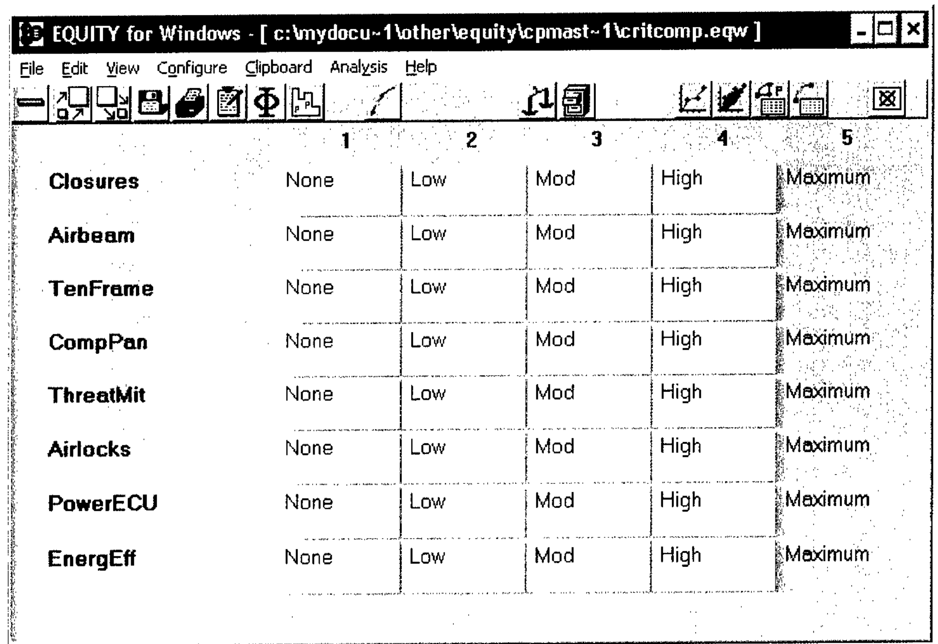


Figure 10. Critical Components Technology Investment Model

The model produces a Pareto diagram of all possible combinations of funding levels with a maximum of 1000 relative benefit points (Figure 11). However, even if the highest investment was made on all technologies (total of $43 M) the BAM could not expect to achieve more than about 73% of the maximum benefit because of uncertainty about the success of the develop efforts (731 out of 1000 points).

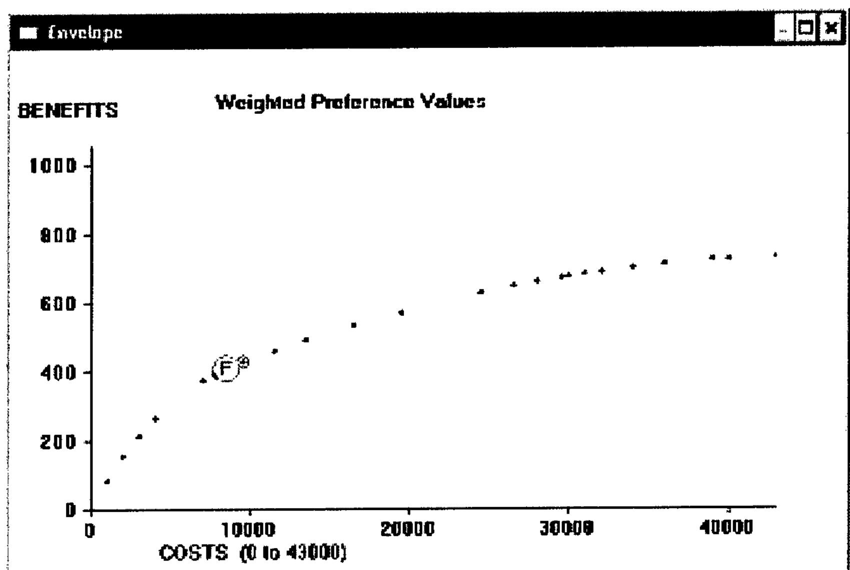


Figure 11. Critical Components Pareto Diagram

The green shaded area at the top of the diagram shows where these "infeasible" strategies lie. The set of optimum frontier strategies, therefore, lies along the top edge of the yellow shaded area of feasible strategies.

In this technology thrust area, there appears to be a clear "knee" on the frontier curve. The "F" point along the frontier shows a best value strategy, where for a little less than 20% of the total cost, or $8.5 M, the program could achieve 409 points, or 55% of the feasible benefit. This suggested best value strategy is shown in Figure 12.

Frontier package

Frontier Pack #7			Preference Values			
			COSTS		BENEFITS	
	TECH	LEVEL	Cost	Total	Benefit	Total
1	Closures	2 Low	3000	3000	108	108
2	Airbeam	2 Low	1000	1000	72	72
3	TenFrame	< 2 Low	500	500	11	11
4	CompPan	2 Low	1000	1000	26	26
5	ThreatMit	2 Low	1000	1000	51	51
6	Airlocks	2 Low	1000	1000	83	83
7	PowerECU	2 Low	1000	1000	59	59
8	EnergEff	> 1 None	0	0	0	0
Frontier package			8500	8500	409	409
Next Package #8			9500	9500	429	429
Previous Pack #6			8000	8000	398	398

Figure 12. Critical Components Best Value Strategy

For each technology category, the recommended level of investment is shown in the LEVEL column. The RED arrow indicates the level that would be increased next if additional funds were invested (the next "buy"). The RED Next Package #8 shows the total cost and benefit of that "next" strategy. The BLUE arrow indicates the level that would be reduced next if funds were cut (the next "sell"). The BLUE Previous Package #6 shows the total cost and benefit of that "previous" strategy.

The COSTS and BENEFITS columns show the costs and benefits for each technology category at the recommended levels. The Total columns are the same as the Cost and Benefit columns because there are only one type of cost and one type of benefit in the model.

The complete Order of Buy for Critical Components is shown in Figure 13. This is the investment list that the BAM should follow in order to maximize the value of his investments at any cumulative level of funding. The best value strategy is shown at increment #7.

	TECH		Order of Buy LEVEL		COSTS INC	CUM	BENEFITS INC	CUM
#0	1 -	Closures	1	None	0	0	0	0
#0	2 -	Airbeam	1	None	0	0	0	0
#0	3 -	TenFrame	1	None	0	0	0	0
#0	4 -	CompPan	1	None	0	0	0	0
#0	5 -	ThreatMit	1	None	0	0	0	0
#0	6 -	Airlocks	1	None	0	0	0	0
#0	7 -	PowerECU	1	None	0	0	0	0
#0	8 -	EnergEff	1	None	0	0	0	0
#1	6 -	Airlocks	2	Low	1000	1000	83	83
#2	2 -	Airbeam	2	Low	1000	2000	72	155
#3	7 -	PowerECU	2	Low	1000	3000	59	214
#4	5 -	ThreatMit	2	Low	1000	4000	51	264
#5	1 -	Closures	2	Low	3000	7000	108	372
#6	4 -	CompPan	2	Low	1000	8000	26	398
#7	3 -	TenFrame	2	Low	500	8500	11	409
#8	8 -	EnergEff	2	Low	1000	9500	20	429
#9	7 -	PowerECU	3	Mod	2000	11500	32	461
#10	6 -	Airlocks	3	Mod	2000	13500	30	491
#11	6 -	Airlocks	4	High	3000	16500	43	534
#12	1 -	Closures	3	Mod	3000	19500	35	569
*13	1 -	Closures	4	High	5000	24500	58	627
#14	5 -	ThreatMit	3	Mod	2000	26500	23	650
#15	2 -	Airbeam	3	Mod	1500	28000	12	662
*16	2 -	Airbeam	4	High	1500	29500	12	673
#17	3 -	TenFrame	3	Mod	500	30000	3	677
#18	4 -	CompPan	3	Mod	1000	31000	6	683
*19	4 -	CompPan	4	High	1000	32000	6	689
#20	5 -	ThreatMit	4	High	2000	34000	11	701
#21	8 -	EnergEff	3	Mod	2000	36000	11	711
#22	7 -	PowerECU	4	High	3000	39000	11	722
#23	3 -	TenFrame	4	High	1000	40000	3	726
#24	8 -	EnergEff	4	High	3000	43000	5	731

Figure 13. Critical Components Order of Buy

3. WORKING GROUP VALIDATION SESSIONS

The COLPRO Master Planning Working Groups (WG) met on August 14 (Air Purification) and August 15, 2002 (Shelters) at the Edgewood Chemical and Biological Center, Aberdeen Proving Ground, MD. Each group consisted of the BAM and 6 to 8 subject matter experts. The objective of the meetings was to validate the initial models developed by the BAM. See Appendix B for the list of participating SMEs.

3.1 Air Purification.

Before making any assessments, the Air Purification Working Group revised the structure of the initial model in order to develop the technology investment strategy at a higher level. The intent was to simplify the model for resource allocation purposes.

3.1.1 WG Air Purification Model.

The Working Group consolidated the eight high priority technology categories into five technology categories. Table 6 shows the technology categories from the Master Plan and the consolidated categories from the Working Group session.

Table 6. Air Purification Model Structures

Master Plan Categories	Working Group Categories
Open/Closed O2 Supply	Open/Closed O2 Supply
Catalytic Oxidation	Catalytic Oxidation
Regenerable Technologies	Regenerable Technologies
Non-Carbon Materials	Single Pass
Activated/Impregnated Carbon	
Engineered Composite Materials	
Non-Membrane Filters	Aerosol-Particulate Removal
Fiber Filter Treatments	

The first input to the WG technology investment model was an assessment of the payoffs, or marginal value, of increased spending in the technology. In other words, how much better would the expected outcome be if we increased investment from a "low" level to a "moderate" level? How much better would it be if we increased investment from a "moderate" level to a "high" level?

The AP Working Group expressed a highly "risk seeking" preference toward investment in this technology development environment. In other words, participants believe that there is not much relative benefit to achieving only minimal or partial successes (1 to 10%). A significant increase in benefit only comes from a completely successful development effort (Table 7).

Table 7. Comparison of Relative Benefit

	Initial Benefit Levels	WG Benefit Levels
Complete Success	100	100
Partial Success	55	10
Minimal Success	10	1
No Success	0	0

For purpose of comparison to the initial model developed by the BAM, the initial benefit levels were used in the WG EQUITY model. The revised WG benefit levels were then used to see what impact it would have on the resulting order of buy.

The AP Working Group then developed relative weights for the revised technology categories. The weights shown in Table 8 are "global weights" meaning that the weights in each column are normalized to sum to 1.0.

Table 8. Working Group Weights for AP

<table>
<tr><th>Master Plan Categories</th><th>Initial Model Weights</th><th>Working Group Categories</th><th>WG Model Weights</th></tr>
<tr><td>Open/Closed O2 Supply</td><td>.21</td><td>Open/Closed O2 Supply</td><td>.03</td></tr>
<tr><td>Catalytic Oxidation</td><td>.19</td><td>Catalytic Oxidation</td><td>.11</td></tr>
<tr><td>Regenerable Technologies</td><td>.17</td><td>Regenerable Technologies</td><td>.40</td></tr>
<tr><td>Non-Carbon Materials</td><td>.08</td><td rowspan="3">Single Pass</td><td rowspan="3">.28</td></tr>
<tr><td>Activated/Impregnated Carbon</td><td>.13</td></tr>
<tr><td>Engineered Composite Materials</td><td>.06</td></tr>
<tr><td>Non-Membrane Filters</td><td>.08</td><td rowspan="2">Aerosol-Particulate Removal</td><td rowspan="2">.18</td></tr>
<tr><td>Fiber Filter Treatments</td><td>.08</td></tr>
</table>

The WG model weights varied significantly from the initial model. The WG discounted the potential impact of the O2 Supply technologies because participants believed they would not be feasible for the range of future systems requiring collective protection. The weight on CatOx was reduced for similar reasons.

The WG redistributed more weight to Regenerable Technologies because of the great potential to revolutionize the logistical support required of collective protection systems in the field.

Finally, the working group assessed probabilities of success for each funding level. These are shown in Table 9, along with the priorities and probability-adjusted benefits.

3.1.2 WG AP Technology Investment Strategy.

The WG Air Purification model structure is shown in Figure 14. Each technology category was treated as a separate investment area (row) within the model. For each potential investment level along a row, the cumulative costs and probability-adjusted benefits were assigned (from Table 9).

Table 9. Air Purification WG Model Inputs

Technologies				Program Outcome Probability of Success				Technology Weight	Probability Adjusted Benefits
				Minimal	Partial	Complete	Total Prob.		
O2 Supply	Investment Level ($000)	Low	$5,000	0.85	0.13	0.02	1.00	3%	17.7
		Moderate	$10,000	0.65	0.30	0.05	1.00		28.0
		High	$15,000	0.45	0.40	0.15	1.00		41.5
	Technology Benefit			10	55	100			
CatOx	Investment Level ($000)	Low	$5,000	0.15	0.50	0.35	1.00	11%	64.0
		Moderate	$10,000	0.10	0.40	0.50	1.00		73.0
		High	$15,000	0.05	0.30	0.65	1.00		82.0
	Technology Benefit			10	55	100			
Regen	Investment Level ($000)	Low	$6,500	0.30	0.25	0.45	1.00	40%	61.8
		Moderate	$13,000	0.10	0.35	0.55	1.00		75.3
		High	$19,500	0.05	0.25	0.70	1.00		84.3
	Technology Benefit			10	55	100			
Single-pass	Investment Level ($000)	Low	$2,500	0.15	0.30	0.55	1.00	28%	73.0
		Moderate	$5,000	0.05	0.20	0.75	1.00		86.5
		High	$7,500	0.02	0.08	0.90	1.00		94.6
	Technology Benefit			10	55	100			
Aerosol-Particulate Removal	Investment Level ($000)	Low	$3,000	0.30	0.35	0.35	1.00	18%	57.3
		Moderate	$6,000	0.15	0.35	0.50	1.00		70.8
		High	$9,000	0.05	0.25	0.70	1.00		84.3
	Technology Benefit			10	55	100			

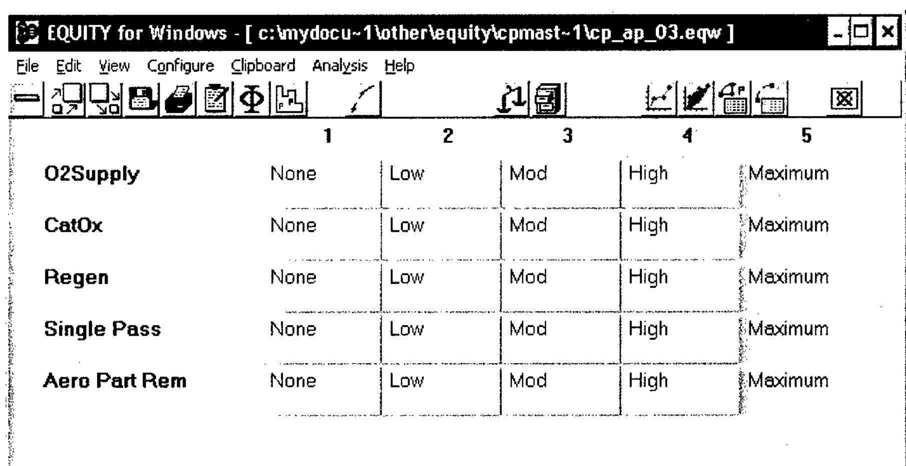


Figure 14. WG Air Purification Technology Investment Model

The model produces a Pareto diagram of all possible combinations of funding levels with a maximum of 1000 relative benefit points (Figure 15). However, even if the highest investment was made on all technologies (total of $66 M) the BAM could not expect to achieve more than about 86% of the maximum benefit because of uncertainty about the success of the development efforts (856 out of 1000 points).

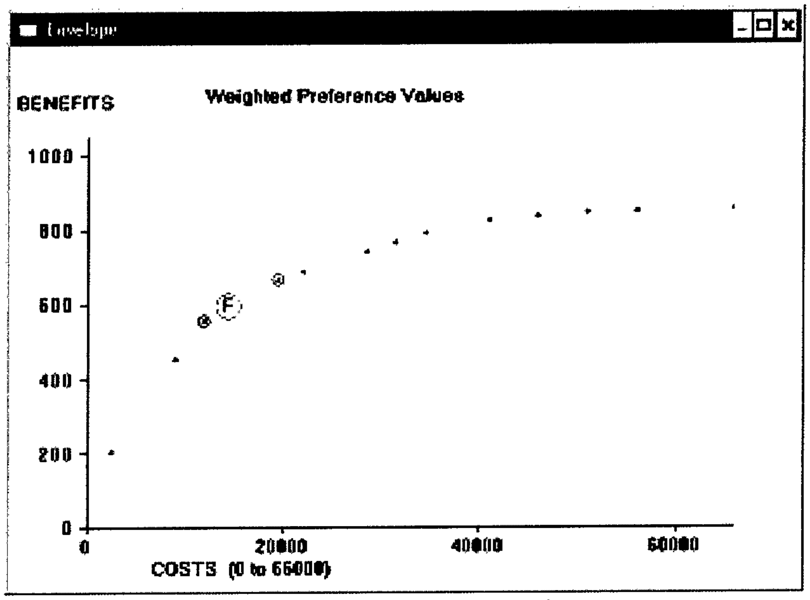


Figure 15. WG AP Pareto Diagram

The green shaded area at the top of the diagram shows where these "infeasible" strategies lie. The set of optimum frontier strategies, therefore, lies along the top edge of the yellow shaded area of feasible strategies.

This WG model compares with the initial AP model as shown in Table 10.

Table 10. Comparison of AP Models

	Maximum Investment	Total Possible Benefit
Initial Model	$64.2 M	593
WG Model	$66 M	856

There was a small difference in the maximum investments because the working group made slightly different assumptions as they rolled the eight categories into five categories. The difference in total possible benefits reflects the working group's more optimistic assessments of probabilities of successful development efforts.

As opposed to the initial model, where the frontier curve was smooth with no clear "knee," the WG model shows a definite best value strategy. The "F" point along the frontier shows the best value strategy, where for a little more than 20% of the total cost, or $14.5 M, the program could achieve 593 points, or nearly 70% of the feasible benefit. This WG AP best value strategy is shown in Figure 16.

Frontier package

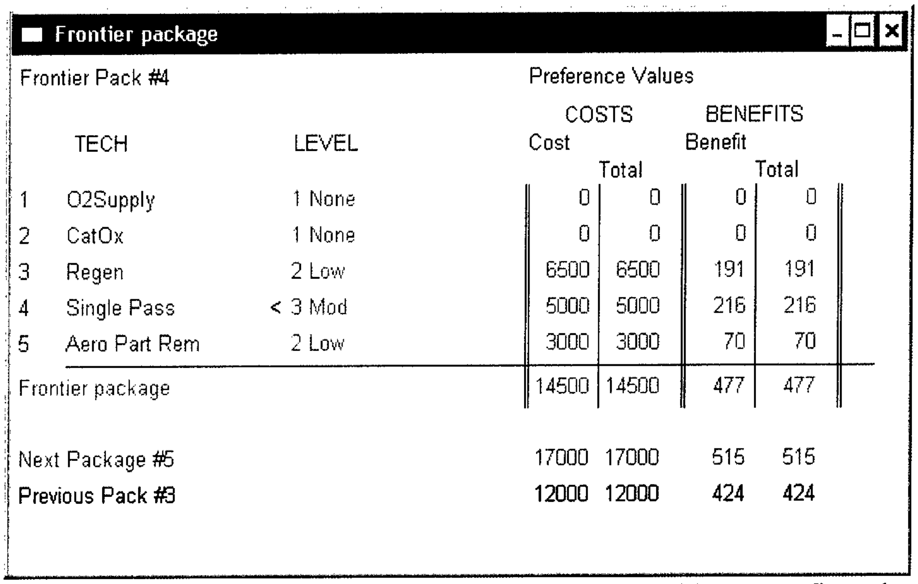
Frontier Pack #4 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	O2Supply	1 None	0	0	0	0
2	CatOx	> 1 None	0	0	0	0
3	Regen	2 Low	6500	6500	247	247
4	Single Pass	< 3 Mod	5000	5000	242	242
5	Aero Part Rem	2 Low	3000	3000	103	103
Frontier package			14500	14500	593	593
Next Package #5			19500	19500	663	663
Previous Pack #3			12000	12000	555	555

Figure 16. AP WG Best Value Strategy

For each technology category, the recommended level of investment is shown in the LEVEL column. The RED arrow indicates the level that would be increased next if additional funds were invested (the next "buy"). The RED Next Package #5 shows the total cost and benefit of that "next" strategy. The BLUE arrow indicates the level that would be reduced next if funds were cut (the next "sell"). The BLUE Previous Package #3 shows the total cost and benefit of that "previous" strategy.

The COSTS and BENEFITS columns show the costs and benefits for each technology category at the recommended levels. The Total columns are the same as the Cost and Benefit columns because there are only one type of cost and one type of benefit in the model. Using the "risk seeking" benefit values that the AP working group assessed, instead of the BAM's "risk neutral" values (Table 7), gives model results that are very similar in the best value investment strategy (Figure 17). The difference lies, as expected, in a reduction in the overall assessed value of the strategy (477 benefit points versus 593 benefit points using "risk neutral" benefit values). This reflects a view that low to moderate investments in the AP technology thrust area would not return proportional benefits—it would be more efficient to invest at high levels or not at all.



Frontier package

Frontier Pack #4 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	O2Supply	1 None	0	0	0	0
2	CatOx	1 None	0	0	0	0
3	Regen	2 Low	6500	6500	191	191
4	Single Pass	< 3 Mod	5000	5000	216	216
5	Aero Part Rem	2 Low	3000	3000	70	70
Frontier package			14500	14500	477	477
Next Package #5			17000	17000	515	515
Previous Pack #3			12000	12000	424	424

Figure 17. AP WG Best Value Strategy with Risk Seeking Benefit Values

This WG best value strategy is significantly different from the BAM's initial best value strategy (Table 11). Even investing 50% of the approximately $64 M maximum, the BAM's initial assessment model showed that only a relatively modest 64% of the feasible benefit could be achieved. In contrast, the WG believed that only a 20% investment could achieve high benefits of 70%. If the investment level in the BAM's initial model is reduced to 20%, the optimal strategy only achieves 38% of expected benefits.

Table 11. Comparison of Air Purification Best Value Strategies

	Percent of Total Possible Investment	**Percent of Total Possible Benefits**
Initial Model	50%	64%
WG Model	20%	70%
Initial Model w/reduced investment	20%	38%

The complete Order of Buy for the WG AP is shown in Figure 18. According to the WG, this is the investment list that the BAM should follow in order to maximize the value of his investments at any cumulative level of funding. The best value strategy is shown at increment #4.

Because the WG consolidated the technology categories from 8 to 5, it is not possible to directly compare the differences among the Order of Buy lists. However, comparing Figure 18 to Figure 5, it is easy to see that the biggest difference is the almost total lack of value placed on the O2 Supply technology by the WG. Because O2 Supply is an expensive program (Table 9), the WG was able to show more relative benefit from an investment strategy focusing on Single Pass and other technologies.

	TECH		LEVEL		COSTS INC	COSTS CUM	BENEFITS INC	BENEFITS CUM
#0	1 -	O2Supply	1	None	0	0	0	0
#0	2 -	CatOx	1	None	0	0	0	0
#0	3 -	Regen	1	None	0	0	0	0
#0	4 -	Single Pass	1	None	0	0	0	0
#0	5 -	Aero Part Rem	1	None	0	0	0	0
#1	4 -	Single Pass	2	Low	2500	2500	204	204
#2	3 -	Regen	2	Low	6500	9000	247	452
#3	5 -	Aero Part Rem	2	Low	3000	12000	103	555
#4	4 -	Single Pass	3	Mod	2500	14500	38	593
#5	2 -	CatOx	2	Low	5000	19500	70	663
#6	4 -	Single Pass	4	High	2500	22000	23	686
#7	3 -	Regen	3	Mod	6500	28500	54	740
#8	5 -	Aero Part Rem	3	Mod	3000	31500	24	764
*9	5 -	Aero Part Rem	4	High	3000	34500	24	788
#10	3 -	Regen	4	High	6500	41000	36	824
#11	2 -	CatOx	3	Mod	5000	46000	10	834
*12	2 -	CatOx	4	High	5000	51000	10	844
#13	1 -	O2Supply	2	Low	5000	56000	5	849
#14	1 -	O2Supply	4	High	10000	66000	7	856

Order of Buy

Figure 18. AP WG Order of Buy

3.2 Shelters.

The Shelters Working Group was unable to validate the Shelter Materials and Treatments initial model because the participants believed that the model was too detailed for the level of information available at this time. As an alternative, the group developed a new model, which included the Shelter Materials and Treatments technologies and the CP Critical Components technology thrust area.

3.2.1 WG Shelters Model.

The Working Group combined the seven high potential Materials and Treatments technologies into a single rating area called Materials (Table 12), which included the technology categories of Moisture-Vapor Permeable Materials, Impermeable Barrier Materials, and Material Treatments.

Table 12. Consolidated Materials Technologies

Master Plan Categories	Working Group Category
1. Selectively Permeable Membranes	1. Materials
2. Semipermeable Membranes	
3. Homogeneous Materials	
4. Heterogeneous Materials	
5. Multilayer Materials	
6. Active/Reactive Treatments	
7. High Surface Tension Treatments	

The Critical Components, Structural Supports and Studies and Analyses technology categories identified by the Fall 2001 Battelle meeting panel were consolidated from eight categories to five categories (Table 13).

Table 13. Consolidated Critical Component Technologies

Battelle Meeting Technologies	Working Group Technologies
1. Novel Closures, Seams and Seals	1. Closures and Seals
	2. Seams
2. Air Beam Technologies	3. Structural Supports
3. Tension Frame/Fabric	
4. Composite Frames	
5. Next Gen Air Locks, Barriers, Doors	4. Airlocks
6. Integrated Power and ECU Control System	5. Environmental Controls
7. Threat Mitigation Methodologies	**Not Included in WG model
8. Energy Efficient Materials Development	**Not Included in WG model

In the Shelters Area, the working group had difficulty initially assessing the probabilities of success in terms of minimal, partial, and complete success, because the transition objectives were not well defined. Instead, for each technology area, the working group assessed the probability of achieving some kind of transition (incremental or breakthrough) every two-to-three years over the ten-year program period given a level of funding. Incremental transitions allow marginal improvements to the existing systems. Breakthrough transitions allow much better systems to be developed. This "Success" probability was entered in the "Complete" success column (Table 14).

The WG used the assumption that a Moderate funding level was "nominal" to pursue 6.2 development in this area, and that a Low and High funding levels cost 50% less and 50% more respectively.

Table 14. WG Shelters Model Inputs

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Technology Weight	Probability Adjusted Benefits
Materials	Investment Level ($000)	Low	$13,000	0.00	0.50	0.50	1.00	50%	50.0
		Moderate	$26,000	0.00	0.25	0.75	1.00		75.0
		High	$39,000	0.00	0.15	0.85	1.00		85.0
	Technology Benefit			0	0	100			
Airlocks	Investment Level ($000)	Low	$2,250	0.00	0.40	0.60	1.00	16%	60.0
		Moderate	$4,500	0.00	0.10	0.90	1.00		90.0
		High	$6,750	0.00	0.05	0.95	1.00		95.0
	Technology Benefit			0	0	100			
Environ. Control	Investment Level ($000)	Low	$2,250	0.00	0.40	0.60	1.00	6%	60.0
		Moderate	$4,500	0.00	0.20	0.80	1.00		80.0
		High	$6,750	0.00	0.10	0.90	1.00		90.0
	Technology Benefit			0	0	100			
Structural Support	Investment Level ($000)	Low	$1,500	0.00	0.80	0.20	1.00	2%	20.0
		Moderate	$3,000	0.00	0.60	0.40	1.00		40.0
		High	$4,500	0.00	0.20	0.80	1.00		80.0
	Technology Benefit			0	0	100			
Closures/Seals	Investment Level ($000)	Low	$2,750	0.00	0.40	0.60	1.00	15%	60.0
		Moderate	$5,500	0.00	0.10	0.90	1.00		90.0
		High	$8,250	0.00	0.00	1.00	1.00		100.0
	Technology Benefit			0	0	100			
Seams	Investment Level ($000)	Low	$2,750	0.00	0.35	0.65	1.00	11%	65.0
		Moderate	$5,500	0.00	0.20	0.80	1.00		80.0
		High	$8,250	0.00	0.06	0.94	1.00		94.0
	Technology Benefit			0	0	100			

The working group assessed the Materials technology thrust area as a roll-up of the three technology categories: Moisture-Vapor Permeable Materials, Impermeable Barrier Materials and Material Treatments. As stated above, the working group assumed that the technical approach in this area would be to make multiple, incremental improvements or breakthrough transitions every few years over the ten-year timeframe.

The Shelters group assessed the probability of "success" – "success" was only considered at the "Complete Success" level by the WG – for each investment level, but did not attempt to assign probabilities to various degrees of success (Complete, Partial, and Minimal). The group made separate success probability assessments for Impermeable Materials and Permeable Materials, but did not assess success probabilities for Material Treatments. The group then assessed an "average" success probability across all Material technologies (Table 15).

Table 15. Materials

	Approx. Funding for 10 Years	P(Success) Impermeable Materials	P(Success) Permeable Materials	P(Success) Average
High Funding Level	$39M	98%	60%	85%
Moderate Funding Level	$26M	95%	50%	75%
Low Funding Level	$13M	85%	10%	50%

The moderate level of funding in Table 15 was obtained by summing the "high" level of funding as assessed by the BAM. The WG then added 50% and subtracted 50% to get the "low" and "high" levels for the above chart.

The working group developed the following representative transition objectives for the Airlocks technology category based on a Moderate funding level.

- Reduce dwell time (< 3 min)
- Reduce weight and volume
- Reduce purge air volume (total amount of air)
- Reduce energy loss due to air loss

The group then determined a funding level for a ten-year period along with a probability of success at each funding level for the Airlock technologies (Table 16).

Table 16. Airlocks

	WG Model Funding for 10 Years	Initial Model Funding for 10 Years	WG Model P(Success)	Initial Model P(Success)
High Funding Level	$6.75M	$6M	95%	90%
Moderate Funding Level	$4.5M	$3M	90%	70%
Low Funding Level	$2.25M	$1M	60%	55%

The working group developed the following representative transition objectives for the Closures/Seals technology category based on a Moderate funding level.

- Reduce leakage rate
- Improve ease of manufacturing
- Improve ease of use
- Contractors to make incremental improvements
- Transitioning something to 6.4, incremental or breakthrough, within 3 years

The group then determined a funding level for a ten-year period along with a probability of success at each funding level for the Closures and Seals technologies (Table 17).

Table 17. Closures and Seals

	WG Model Funding for 10 Years	Initial Model Funding for 10 Years	WG Model P(Success)	Initial Model P(Success)
High Funding Level	$8.25M	$11M	100%	90%
Moderate Funding Level	$5.5M	$6M	90%	70%
Low Funding Level	$2.7M	$3M	60%	50%

The working group developed the following representative transition objectives for the Environmental Controls technology category based on a Moderate funding level.

- Weight and Volume
- Energy Demands
- Maintainability
- Integrated System (Filter, Blower, Heat, AC, Power)
- Scalability
- Contractors to make incremental improvements

The group then determined a funding level for a ten-year period along with a probability of success at each funding level for the Environmental Controls technologies (Table 18).

Table 18. Environmental Controls

	WG Model Funding for 10 Years	Initial Model Funding for 10 Years	WG Model P(Success)	Initial Model P(Success)
High Funding Level	$6.75M	$6M	90%	80%
Moderate Funding Level	$4.5M	$3M	80%	70%
Low Funding Level	$2.25M	$1M	60%	45%

The working group developed the following representative transition objectives for the Seams technology category based on a Moderate funding level.

- Manufacturability
- Durability
- Efficacy
- Universally Applicable
- Field Repairable
- Multiple Techs

The group then determined a funding level for a ten-year period along with a probability of success at each funding level for the Seams technologies (Table 19).

Table 19. Seams

	WG Model Funding for 10 Years	Initial Model Funding for 10 Years	WG Model P(Success)	Initial Model P(Success)
High Funding Level	$8.25M	$11M	100%	90%
Moderate Funding Level	$5.5M	$6M	100%	70%
Low Funding Level	$2.75M	$3M	100%	50%

The working group developed the following representative transition objectives for the Structural Support technology category based on a Moderate funding level.

- Airbeams
- Shelter that does not require a liner
- Integration
- Reduce weight, volume, and O&M
- Tension Frame Fabric
- Turn into a CB barrier
- Composite Frame Hinge

The group then determined a funding level for a ten-year period along with a probability of success at each funding level for the Structural Supports technologies (Table 20).

Table 20. Structural Supports

	WG Model Funding for 10 Years	**Initial Model Funding for 10 Years**	**WG Model P(Success)**	**Initial Model Average P(Success)**
High Funding Level	$4.5M	$9M	80%	78%
Moderate Funding Level	$3M	$5.5M	40%	67%
Low Funding Level	$1.5M	$2.5M	20%	55%

The Shelters Working Group then developed relative weights for the revised technology categories. The weights shown in Table 21 are "global weights" meaning that the weights in each column are normalized to sum to 1.0. The weights in the left column were developed during the Master Planning meeting for the CP business area.

Table 21. WG Weights for Shelters

Battelle Meeting Technologies	**Weights**	**Working Group Technologies**	**Weights**
Materials	.50	Materials	.50
1. Novel Closures, Seams and Seals	.13	1. Closures and Seals	.15
		2. Seams	.11
2. Air Beam Technologies	.07		
3. Tension Frame/Fabric	.01	3. Structural Supports	.02
4. Composite Frames	.03		
5. Next Gen Air Locks, Barriers, Doors	.10	4. Airlocks	.16
6. Integrated Power and ECU Control System	.08	5. Environmental Controls	.06
7. Threat Mitigation Methodologies	.05	**Not Included in Model	
8. Energy Efficient Materials Development	.03	**Not Included in Model	

3.2.2 <u>WG Shelters Technology Investment Strategy</u>.

The next figure shows the strategy model framework as modified by the Shelters Working Group (Figure 19).

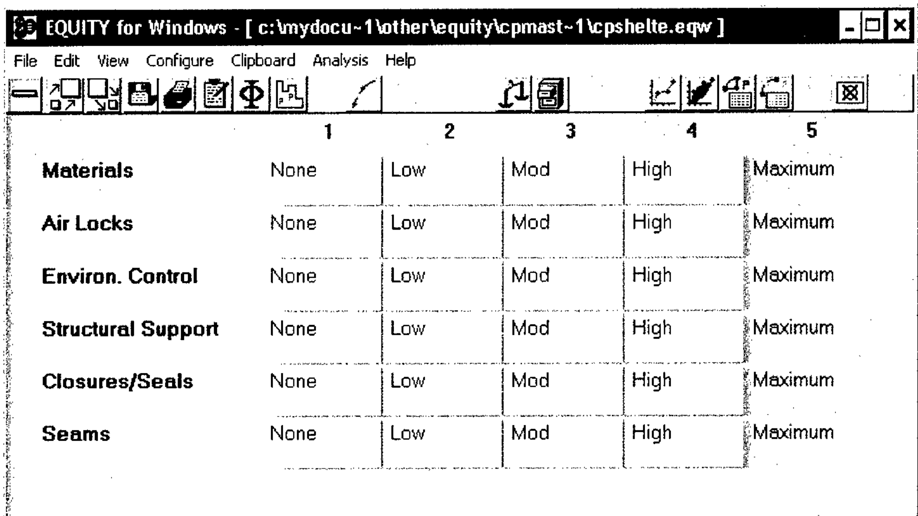


Figure 19. WG Shelters Technology Investment Model

The model produces a Pareto diagram of all possible combinations of funding levels with a maximum of 1000 relative benefit points (Figure 20). However, even if the highest investment was made on all technologies (total of $73.5 M) the BAM could not expect to achieve more than about 90% of the maximum benefit because of uncertainty about the success of the develop efforts (900 out of 1000 points).

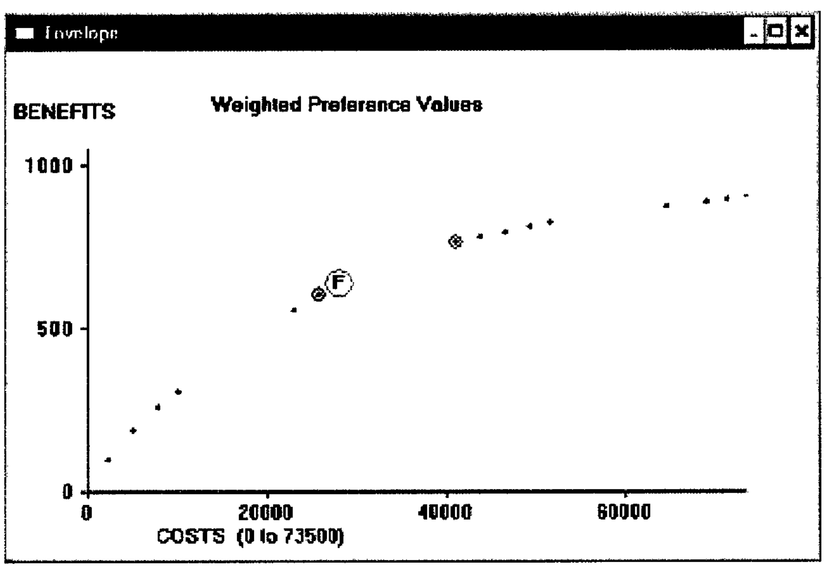


Figure 20. WG Shelters Pareto Diagram

The green shaded area at the top of the diagram shows where these "infeasible" strategies lie. The set of optimum frontier strategies, therefore, lies along the top edge of the yellow shaded area of feasible strategies.

It is not possible to compare this WG model with the initial Shelter Materials and Treatments model and the Critical Components model because the model structures are so different.

The WG Shelters model shows a frontier curve that is smooth with no clear "knee" for a best value strategy. However, the "F" point along the frontier shows a suggested best value strategy, where for a little more than one-third of the total cost, or $28 M, the program could achieve 637 points, or a little more than 70% of the feasible benefit. This WG Shelters best value strategy is shown in Figure 21.

Frontier package

Frontier Pack #7 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	Materials	> 2 Low	13000	13000	250	250
2	Air Locks	3 Mod	4500	4500	144	144
3	Environ. Control	< 2 Low	2250	2250	36	36
4	Structural Support	1 None	0	0	0	0
5	Closures/Seals	3 Mod	5500	5500	135	135
6	Seams	2 Low	2750	2750	72	72
Frontier package			28000	28000	637	637
Next Package #8			41000	41000	762	762
Previous Pack #6			25750	25750	601	601

Figure 21. WG Shelters Best Value Strategy

For each technology category, the recommended level of investment is shown in the LEVEL column. The RED arrow indicates the level that would be increased next if additional funds were invested (the next "buy"). The RED Next Package #8 shows the total cost and benefit of that "next" strategy. The BLUE arrow indicates the level that would be reduced next if funds were cut (the next "sell"). The BLUE Previous Package #6 shows the total cost and benefit of that "previous" strategy.

The COSTS and BENEFITS columns show the costs and benefits for each technology category at the recommended levels. The Total columns are the same as the Cost and Benefit columns because there are only one type of cost and one type of benefit in the model.

The complete Order of Buy for the WG Shelters model is shown in Figure 22. According to the WG, this is the investment list that the BAM should follow in order to maximize the value of his investments at any cumulative level of funding. The best value strategy is shown at increment #7.

Order of Buy

Order of Buy

	TECH		LEVEL		COSTS INC	COSTS CUM	BENEFITS INC	BENEFITS CUM
#0	1 -	Materials	1	None	0	0	0	0
#0	2 -	Air Locks	1	None	0	0	0	0
#0	3 -	Environ. Control	1	None	0	0	0	0
#0	4 -	Structural Support	1	None	0	0	0	0
#0	5 -	Closures/Seals	1	None	0	0	0	0
#0	6 -	Seams	1	None	0	0	0	0
#1	2 -	Air Locks	2	Low	2250	2250	96	96
#2	5 -	Closures/Seals	2	Low	2750	5000	90	186
#3	6 -	Seams	2	Low	2750	7750	72	258
#4	2 -	Air Locks	3	Mod	2250	10000	48	306
#5	1 -	Materials	2	Low	13000	23000	250	556
#6	5 -	Closures/Seals	3	Mod	2750	25750	45	601
#7	3 -	Environ. Control	2	Low	2250	28000	36	637
#8	1 -	Materials	3	Mod	13000	41000	125	762
#9	6 -	Seams	3	Mod	2750	43750	17	778
#10	6 -	Seams	4	High	2750	46500	15	793
#11	5 -	Closures/Seals	4	High	2750	49250	15	808
#12	3 -	Environ. Control	3	Mod	2250	51500	12	820
#13	1 -	Materials	4	High	13000	64500	50	870
#14	4 -	Structural Support	4	High	4500	69000	16	886
*15	2 -	Air Locks	4	High	2250	71250	8	894
#16	3 -	Environ. Control	4	High	2250	73500	6	900

Figure 22. WG Shelters Order of Buy

Finally, the Shelters Working Group conducted a direct resource allocation exercise to assess the participants' "instinctive" judgment about how available near term funds should be spent. The participants were asked, "If $1 million were available in the next fiscal year for the Shelters Area, what percent should be allocated to each of the six technology categories?" The six individual participants' assessments (shown as A through F) and the numerical average are shown in Table 22.

Table 22. WG Shelters Direct Resource Allocation

Shelters	A	B	C	D	E	F	Average
Materials	58.5	25	25	30	20	30	31.4
Airlocks	12	20	25	20	30	25	22.0
ClosuresSeals	15	15	20	20	20	10	16.7
Env Control	10	20	20	10	10	15	14.2
Seams	4.5	15	5	20	10	15	11.6
Struct Spt	0	5	5	0	10	5	4.2
Total Percent	100	100	100	100	100	100	100.0

The equivalent $1M/year strategy in the WG Shelters model is shown in Figure 23, which has a frontier package at exactly $10M over ten years. Because of the large increments of funding used to build the model, the entire $1M would be allocated to only three technology categories: Air Locks (45%), Closures/Seals (27.5%), and Seams (27.5%).

Frontier package

Frontier Pack #4 — Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	Materials	> 1 None	0	0	0	0
2	Air Locks	< 3 Mod	4500	4500	144	144
3	Environ. Control	1 None	0	0	0	0
4	Structural Support	1 None	0	0	0	0
5	Closures/Seals	2 Low	2750	2750	90	90
6	Seams	2 Low	2750	2750	72	72
	Frontier package		10000	10000	306	306
	Next Package #5		23000	23000	556	556
	Previous Pack #3		7750	7750	258	258

Figure 23. WG Shelters Strategy for $1M per Year

However, the "next package" priority increment to the model is the Level 2 (Low Investment) in Materials ($1.3M per year). At this level of total funding ($2.3M per year), the model shows results very similar to the "instinctive" allocation (Table 23).

Table 23. Comparison of Resource Allocation Results for Shelters

Technology Category	**Direct $1M Allocation**	**Model $2.3 M Allocation**
Materials	31.4%	56.5%
Air Locks	22%	20%
Closures/Seals	16.7%	12%
Env Control	14.2%	0%
Seams	11.6%	12%
Structural Spts	4.2%	0%

4. CONCLUSIONS

The Working Group for the Air Purification Technology Thrust Area was not able to confirm the optimal investment strategy for the AP area as identified by the BAM. As shown in Table 24, the strategies are very different. The differences lie in terms of the gross amount of investment needed to gain the bulk of the potential benefits, and in the assessment of the potential value of O2 Supply and Catalytic Oxidation technologies.

Table 24. Comparison of AP Initial and WG Best Value Strategies

Initial Categories	**10 year Investment ($M)**	**WG Categories**	**10 year Investment ($M)**
Open/Closed O2 Supply	$4.5	Open/Closed O2 Supply	$0
Catalytic Oxidation	$5.0	Catalytic Oxidation	$0
Regenerable Technologies	$3.85	Regenerable Technologies	$6.5
Non-Carbon Materials	$1.75	Single Pass	$5.0
Activated/Impregnated Carbon	$4.5		
Engineered Composite Materials	$1.8		
Non-Membrane Filters	$4.5	Aerosol-Particulate Removal	$3.0
Fiber Filter Treatments	$3.0		
Total	$28.9	Total	$14.5

The Working Group for the Shelters and Critical Components Technology Thrust Areas developed a resource allocation model at a high level of aggregation, combining all the Shelter Materials and Treatments into a single "investment area." It is therefore not possible to show whether the group confirmed the BAM's initial investment strategy for shelter materials. However, for Critical Components, the working group came closer to confirming the optimal investment strategy as identified by the BAM (Table 25).

As a next step, the COLPRO community should seek to standardize the investment categories it will use to allocate resources in each budget cycle.

In addition, the BAM should convene SME panels each year to reassess and update the Master Plan resource allocation model to insure a steady course in investment implementation until the next FEA and Master Planning cycle.

Finally, the technology thrust areas should be examined together to produce a single, integrated investment strategy for COLPRO. This will insure the optimal allocation of resources across the business area.

Table 25. Comparison of Shelters Initial and WG Best Value Strategies

Initial Categories	**10-Year Investment ($M)**	**WG Categories**	**10-Year Investment ($M)**
Materials	$5	Materials	$13
1. Novel Closures, Seams and Seals	$3	1. Closures and Seals	$5.5
		2. Seams	$2.75
2. Air Beam Technologies	$1	3. Structural Supports	$0
3. Tension Frame/Fabric	$0.5		
4. Composite Frames	$1		
5. Next Gen Air Locks, Barriers, Doors	$1	4. Airlocks	$4.5
6. Integrated Power and ECU Control System	$1	5. Environmental Controls	$2.25
7. Threat Mitigation Methodologies	$1	**Not Included in Model	
8. Energy Efficient Materials Development	0	**Not Included in Model	
Total	$13.5	Total	$28

APPENDIX A

SUMMARY TABLES FOR MASTER PLAN

The following tables summarize the limitations and gaps, the research approach, resources expected, and estimated risk for the technologies advanced to the Master Plan. Table A-1 summarizes data for the Air Purification technologies, and Table A-2 summarizes Shelter Material and Treatment data.

Table A-1. Air Purification High Potential Technologies Assessment

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Activated/ Impregnated Carbon	• Cost (10% decrease is a goal in developing new carbon materials) • Cannot protect against some high priority TICs, and effectiveness against Future Threat Agents (FTAs) is unknown • Need increased capacity • Need to lower excessive pressure drop • Ignition can occur at high concentrations of agents/TIMs • Disposal of contaminated carbon	• Characterize performance against TICs and FTAs, capacity and pressure drop issues • Investigation/Modeling—Develop and test reactive materials and additives. • Evaluation/Testing—Conduct empirical testing of chemical groups, then modeling	1—3 yrs: 3 MY 4—6 yrs: 2 MY 7—10 yrs: 1 MY Total – 19 MY, $3M	Low
Regenerable Technologies (P/T/ESA)	• TSA and ESA characterization incomplete • Lack of data for protection against FTAs • Expedite desorption of contaminants, specifically those with high breakthrough in passive sorbent systems; more efficient regeneration of sorbent after exposure • How to mitigate off—gassing • Power/heat management	• Characterize optimum TSA "cycle" • Characterize hybrid PSA/TSA systems • Lab testing for protection against high volatility compounds and to minimize regeneration of low volatility agents	1—3 yrs: 6 MY $500K Materials and Equipment 4—6 yrs: 3 MY $500K Materials and Equipment 7—10 yrs: 1 MY Total – 31 MY, $7.7M ($4.7M for Labor, $3M for Materials and Equipment)	Moderate

Table A-1. Air Purification High Potential Technologies Assessment (Continued)

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Engineered Composite Materials	• Design characteristics for materials • Significant gap of performance data for CWAs, TICs, FTAs	• Characterize performance against CWAs, TICs and FTAs, investigate capacity and pressure drop issues • Explore ignition and disposal issues • Investigation/Modeling—Develop and test reactive materials and additives. • Evaluation/Testing—conduct empirical testing of chemical groups, then modeling.	<u>1—3 yrs</u>: 3 MY $200K Materials and Equipment <u>4—6 yrs</u>: 2 MY <u>7—10</u> yrs: 1 MY <u>Total</u> – 19 MY, $3.6M ($3M for Labor, $600K for Materials and Equipment)	High
Non—Carbon Materials	• Cannot protect against certain CWAs, FTAs and high priority TICs • Need increased capacity • Need to evaluate durability/degradation	• Characterize single—pass and multi—pass uses • Characterize CWAs, TICs and FTAs, capacity and pressure drop issues • Explore ignition and disposal issues • Investigation/Modeling—Develop and test reactive materials and additives. • Evaluation/Testing—Conduct empirical testing of chemical groups, then modeling.	<u>1—3 yrs</u>: 2 MY <u>4—6 yrs</u>: 3 MY <u>7—10 yrs</u>: 2 MY <u>Total</u> – 23 MY, $3.5M	Moderate
Catalytic Oxidation	• No/Low NOx & other catalysts (CWA) • Effluent treatment (Acid gasses) • Knowledge of one catalyst against CWAs; no TICs or FTAs have been used in testing	• Characterize performance of no NOx & other catalysts; material balance • Characterize TICs, FTAs, CWAs • Develop treatment process for effluents.	<u>1—3 yrs</u>: 5 MY $500K Materials and Equipment <u>4—6 yrs</u>: 5 MY $500K Materials and Equipment <u>7—10 yrs</u>: 4 MY <u>Total</u> – 46 MY, $10M ($7M for Labor, $3M for Materials and Equipment)	Moderate

Table A-1. Air Purification High Potential Technologies Assessment (Continued)

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Catalytic Oxidation	• No/Low NOx & other catalysts (CWA) • Effluent treatment (Acid gasses) • Knowledge of one catalyst against CWAs; no TICs or FTAs have been used in testing	• Characterize performance of no NOx & other catalysts; material balance • Characterize TICs, FTAs, CWAs • Develop treatment process for effluents.	1—3 yrs: 5 MY $500K Materials and Equipment 4—6 yrs: 5 MY $500K Materials and Equipment 7—10 yrs: 4 MY Total – 46 MY, $10M ($7M for Labor, $3M for Materials and Equipment)	Moderate
Open/Closed Oxygen Supply Technologies	• Limited Applications for Closed Systems • Performance Characterization (military) – Open • Flux • Power • By—products • Durability • Breadth • Fouling • Performance Characterization (military) – Closed • O2 Generation (Dimensions) • Impurities • Scalability (Dimensions) • Power • Closed System Requires Supporting Technologies • Seals • Conditioned Air • Heat/Cooling • CO2 Scrubbing • Makeup/Backup O2	Open— • Literature Review • Feasibility Study • Lab Program (Performance Characterization) Closed— CO_2 Scrubbing • Study ($100K); Application	1—3 yrs: 6 MY $500K Materials and Equipment 4—6 yrs: 4 MY $500K Materials and Equipment 7—10 yrs: 2 MY Total – 38 MY, $9M ($6M for Labor, $3M for Materials and Equipment)	High

Table A-1. Air Purification High Potential Technologies Assessment (Continued)

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Non—Membrane Filters	• Self—cleaning (Regenerable, Reusable) • Increased Capacity • Increased Performance • Limited Efficacy Data • Assessment of Defeat/Degradation Mechanisms	• Material Screening (ID Candidates) • Material Investigations • Literature (existing) • Lab Testing	1—3 yrs: 3 MY 4—6 yrs: 2 MY 7—10 yrs: 1 MY Total – 19 MY, $3M	Low

Fiber Filter Treatments
 	
—Electrostatically Enhanced Filters
 	
—Reactive Fibers/Membranes
 	
Fiber filter treatments include reactive (e.g. Nanoparticles,
 	
Triosyn, enzymes), nonreactive passive (e.g. intrinsic electrostatic), and nonreactive active (e.g. extrinsic electrostatic)).
	• Not a stand—alone system. Provide biocidal enhancement
	• Somewhat greater resources required relative to current system
	• Verify:
	  • Improved Safety
	  • Reduced Pressure Loss
	  • Filter will attain a non—hazardous status (for C&B only, not nuclear)
	  • Extended Life
	  • Added Protection
	  • Reduced Operating and Disposal Costs
	• Improve Collection Efficiency
		• Identify Filter Treatments
		• Assess Candidates
		• Test Candidates
		• Evaluate Results
		• Modeling
			1—3 yrs: 3 MY
			
			4—6 yrs: 2 MY
			
			7—10 yrs: 1 MY
			
			Total – 19 MY, $3M
				Moderate

Table A-2. Shelters High Potential Technologies Assessment

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
MATERIAL TREATMENTS				
High surface tension treatments** Wicking Materials and Treatments** Electrostatic Surface Treatments** Reactive Nanotreatments Active /Reactive Treatments	• Doesn't last long enough • Limited shelf life • Unknown performance / efficacy under normal and adverse condition • Limited number of manufacturers, due to complexity of production, or environmental impact issues • Need: • Characterization data • Increased durability • Improved bonding • Recharge/regenerate (one time application, rather than reapplying) • Better material compatibility with other components • Multi—function capabilities	• Leverage commercial R&D (e.g. Nova HST work) and Individual Protection work • ID treatments (** more mature) • Component and systems/application modeling • Fabric foundation • Market survey	1—3 yrs: 5 MY $300K Equipment $300K Protocol 4—6 yrs: 7 MY $500K Equipment $400K Protocol 7—10 yrs: 4 MY Total: 52 MY + $4.5	Low to Moderat e
ENGINEERED MOISTURE—VAPOR PERMEABLE MATERIALS				

Semi—permeable Membranes
Selectively Permeable Membranes
	Lack of info:
	• Physiological parameters
	• Efficacy
	• Fabric strength
	• Need:
	  • Characterization data
	  • Increased durability (environmental degradation)
	  • Multi—layers/components
		• Leverage IP and other work
		• Characterization
		• Studies and analysis
			1—3 yrs: 5 MY
			$300K Equipment
			$100K Protocol
			
			4—6 yrs: 8 MY
			$700K Equipment
			
			7—10 yrs: 5 MY
			Total: 59MY + $3.3M
				High

Table A-2. Shelters High Potential Technologies Assessment (Continued)

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Nanobarrier Materials				
IMPERMEABLE BARRIER MATERIALS				
Homogeneous Materials Heterogeneous Materials Multilayer Materials	• Cost • Reduce size and weight • Develop multi—functional capability • Develop multi—layer process • Ensure material compatibility • Bonding – Coatings/Laminates • Efficient manufacturing process • NBC Survivable • Decontaminability • Reparability	• Leverage IP and other efforts • Material market survey (trade/market analysis) • Material characterization • Develop manufacturing process • Evaluate material compatibility • Studies	1—3 yrs: 6 MY $400K Equipment 4—6 yrs: 5 MY $100K Equipment $100K Protocols 7—10 yrs: 4 MY Total: 49 MY; + $1.8M	Low to Moderate
STRUCTURAL SUPPORTS				
Novel Closures, Seams and Seals	• Too difficult to seal large structures in field (curved, etc.) • Capacity for repair is low • Operational durability is poor • Reduces inherent protection ability • Interface/compatibility/bonding with shelter materials, vehicles, etc. • Costly • Deployment time is excessive • Incremental improvements such as better flexibility, adaptability, resistance to environmental factors • Look for totally different concepts / out of the box	Two goals: 1. Incremental improvements such as better flexibility, adaptability, resistance to environmental factors 2. Look for totally different concepts / out of the box Market survey (BAA, SBIR) • Innovative research methods, such as brainstorming with industrial designers, manufacturers, etc., university contest	1—3 yrs: 5 MY 4—6 yrs: 7 MY $500K Equipment $100K Protocols 7—10 yrs: 6 MY	High

Table A-2. Shelters High Potential Technologies Assessment (Continued)

Technology	Limitations/ Barriers / Gaps	Research Approach	Resources (Man Years MY)	Risk
Airbeam Technologies Tensioned Frame/Fabric Concept Development Composite Frame w/Integral /Self-Deploying Hinge	• Requires additional equipment to erect and maintain • Bulky • Repairability • Survivability • Scalability • Safety factors • Characterize performance parameters • Understanding failure modes/mechanism parameters • Optimize materials • Improve interfaces • Self deployment • Reusable	• Modeling of performance • Adapt structural mechanical approaches / codes to this application • Modeling large frames	1—3 yrs: 5 MY 4—6 yrs: 5 MY $400K Equip 7—10 yrs: 5 MY	Low to Moderate
CRITICAL / ESSENTIAL COMPONENTS				
Survivability Development and Threat Mitigation Methodologies Next—Generation of Airlocks, Barriers and Doors Integrated Power and ECU Control System (IPECS) Energy Efficient Materials Development		• Short Term Study Areas • Long Term Programs • Survivability against conventional (blast, ballistic) as well as NBC survivability • Will need to consider materials and fabrics for use in shelter components—characterize, study, modeling	1—3 yrs: 12 MY $800K Equip 4—6 yrs: 12 MY $800K Equip 7—10 yrs: 12 MY	Moderate

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APPENDIX B

WORKING GROUP PARTICIPANTS

ORGANIZATION	Working Group	NAME	COMM #	E-Mail
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JTCOPS PM (USA)	AP & Shelters	Mr. Jorge Christian	(410) 436-5512	Jorge.christian@sbccom.apgea.army.mil
AFRL/MLQF (USAF) Filtration	AP & Shelters	Dr. Joe Wander	(850) 283-6240	Joe.wander@tyndall.af.mil
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AAC/WMO (USAF) Combat Support Systems, Program Office CPE integration Sverdrup	AP & Shelters	Mr. Scott Matheson	(850) 882-4684 Ext. 337	Scott.matheson@eglin.af.mil
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APPENDIX C

PRESENTATION TO THE 71ST MORS SYMPOSIUM

Slide 1

Presentation to the 71st MORS Symposium
Working Group 28 – Decision Analysis

Technology Investment Strategy Annex: Collective Protection Front End Analysis and Master Plan Report

Genna Lee Buckless
Freeman Marvin
Trish Vargo
John Walther
Decision Analysis Team/ECBC

12 June 2003

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Slide 2

Outline

- *Background*
- *Purpose & Impact of the Analysis*
- *Analysis Approach*
  - Tools, objectives, analysis framework, results
- *Lessons Learned*

2

Slide 3

Background

- *Collective Protection Front End Analysis*
  - Ranking of viable technologies relative to application areas
- *Collective Protection Master Plan*
  - Select technologies evaluated against other considerations
  - 2 products
    - ID Techs for the Tech Base Program
    - Develop a strategic resource allocation model
  - 4 steps in process
    - Define CP BA framework
    - Assess high potential technologies
    - Prioritize techs and establish time frames for transition
    - *Develop planning models & examine alternative program strategies

3

Slide 4

Purpose & Impact of Analysis

- *Purpose*
  - Develop and examine alternative funding strategies
  - Use funding strategies to create an investment portfolio which is optimized over 10 years
- *Impact*
  - Development of method to make strategic funding decisions for R&D programs

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Slide 5

Analysis Approach

a) Tools

b) Objectives

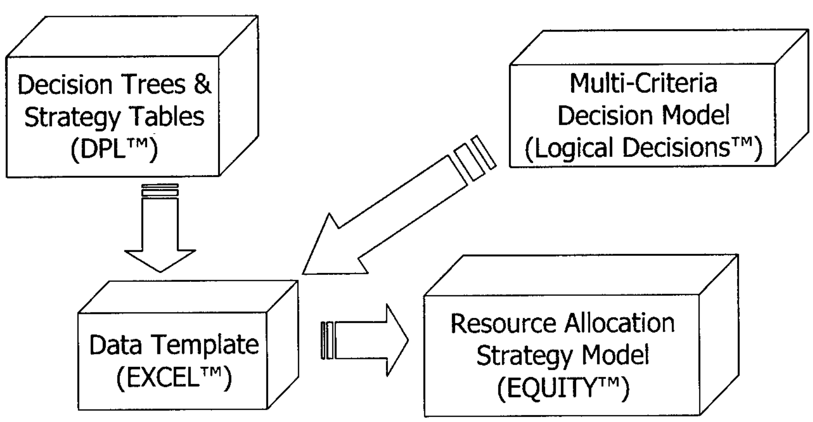
c) Analysis Framework

d) Results

5

Slide 6

Tools



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Slide 7

Objectives

1) Initial Analysis
    - Examine alternative funding strategies
    - Determine optimal set
2) Workgroup Analysis
    - Validate initial models developed by BAM

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Slide 8

Initial Analysis Framework Steps

DPL™
- •Create decision tree model
- •Create strategy tables
- •Estimate:
    - •Cost of alternative investment levels
    - •Probability of success
    - •Technology benefit levels

LDW™ → •Assess overall technology weights

EXCEL™
- •Compile data
- •Compute probability adjusted benefit levels

EQUITY™
- •Examine all possible combinations of technology investments
- •Create an investment portfolio

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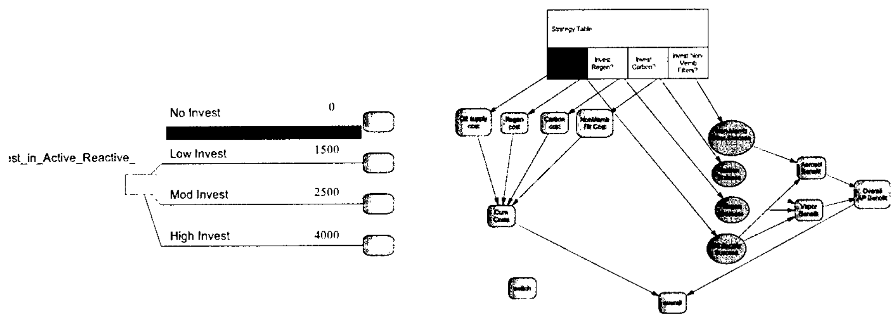
Slide 9

Initial Analysis Framework

Decision Tree and Influence Diagram showing Strategy Table



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Slide 10

Initial Analysis Framework

Strategy Table

	Invest O2 supply?	Invest Regen?	Invest Carbon?	Invest Non-Memb Filters?
Reduced	No Invest	No Invest	No Invest	No Invest
Status quo	Low Invest	Low Invest	Low Invest	Low Invest
Balanced				
Aggressive	Mod Invest	Mod Invest	Mod Invest	Mod Invest
Increased	High Invest	High Invest	High Invest	High Invest
Bruce1				
Bruce2				
Full Investment				

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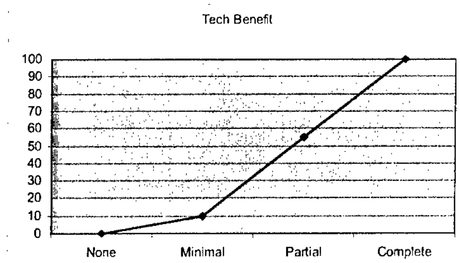
Slide 11

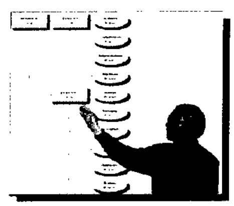
Initial Analysis Framework

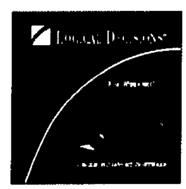


Utility Curve-Tech Benefit

“risk neutral”

(0, 10, 55, 100)





Weights

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Slide 12

Initial Analysis Framework

The “3 Ps”

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Probability Adjusted Benefits	Technology Weight
O2 Supply	Investment Level ($000)	Low	$4,500	0.80	0.15	0.05	1.00	21.25	21%
		Moderate	$9,000	0.50	0.30	0.20	1.00	41.50	
		High	$13,500	0.30	0.40	0.30	1.00	55.00	
			Technology Benefit	10	55	100			

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Slide 13

Initial Analysis Framework

Structure of Investment Areas & Levels

EQUITY for Windows - [c:\mydocu~1\other\equity\cpmast~1\cp_ap_02.eqw]

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	1	2	3	4	5
O2Supply	None	Low	Mod	High	Maximum
CatOx	None	Low	Mod	High	Maximum
Regen	None	Low	Mod	High	Maximum
NonCarbon	None	Low	Mod	High	Maximum
NonMemFilt	None	Low	Mod	High	Maximum
EngComp	None	Low	Mod	High	Maximum
FibFilTreat	None	Low	Mod	High	Maximum
ActCarbon	None	Low	Mod	High	Maximum

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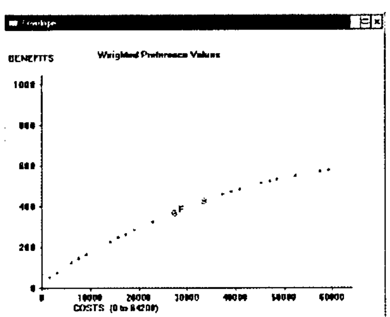
Slide 14

Initial Results



Pareto Diagram

Frontier package

Frontier Pack #12

Preference Values

	TECH	LEVEL	COSTS Cost	COSTS Total	BENEFITS Benefit	BENEFITS Total
1	[illegible]	> 2 Low	4500	4500	45	45
2	[illegible]	2 Low	5000	5000	62	62
3	Regen	2 Low	3000	3000	40	40
4	[illegible]	2 Low	1750	1750	21	21
5	[illegible]	< 4 High	4500	4500	62	62
6	[illegible]	2 Low	1800	1800	20	20
7	[illegible]	3 Mid	3000	3000	44	44
8	[illegible]	4 High	4500	4500	89	89
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
Next Package #13			33400	33400	424	424
Previous Pack #11			27400	27400	367	367

Frontier Package

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Slide 15

Initial Results

Order of Buy

Order of Buy

Order of Buy

	TECH		LEVEL		COSTS INC	COSTS CUM	BENEFITS INC	BENEFITS CUM
#0	1	O2Supply	1	None	0	0	0	0
#0	2 -	CatOx	1	None	0	0	0	0
#0	3 -	Regen	1	None	0	0	0	0
#0	4 -	NonCarbon	1	None	0	0	0	0
#0	5	NonMemFilt	1	None	0	0	0	0
#0	6 -	EngComp	1	None	0	0	0	0
#0	7 -	FibFilTreat	1	None	0	0	0	0
#0	8	ActCarbon	1	None	0	0	0	0
#1	8 -	ActCarbon	2	Low	1500	1500	51	51
#2	7	FibFilTreat	2	Low	1500	3000	24	75
#3	5	NonMemFilt	3	Mod	3000	6000	48	123
#4	8	ActCarbon	3	Mod	1500	7500	20	143
#5	7 -	FibFilTreat	3	Mod	1500	9000	20	163
#6	2 -	CatOx	2	Low	5000	14000	62	225
#7	4 -	NonCarbon	2	Low	1750	15750	21	245
#8	8 -	ActCarbon	4	High	1500	17250	18	263
#9	6 -	EngComp	2	Low	1800	19050	20	283
#10	3 -	Regen	2	Low	3850	22900	40	322
#11	1 -	O2Supply	2	Low	4500	27400	45	367
#12	5 -	NonMemFilt	4	High	1500	28900	14	382

"Best-Value Package"

- Incremental/Cumulative costs
- Line 12

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Slide 16

Workgroup Analysis Framework

- *Intended*
  - Repeat process used in BAM's initial assessment
  - Validate BAM's results
- *Actual*
  - Workgroup restructured the decision model
  - Examined a new set of funding strategies & all of their possible combinations

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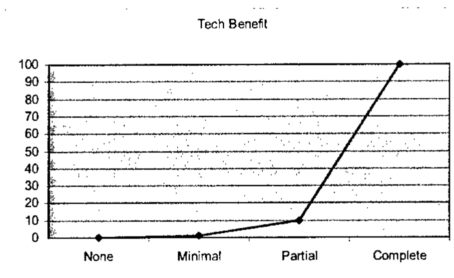
Slide 17

Workgroup Analysis Framework

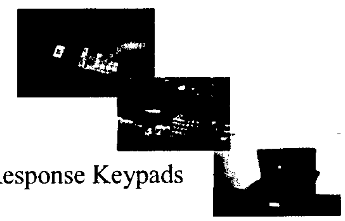
EDGEWOOD
Chemical Biological Center

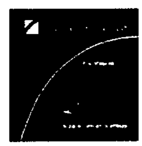


Utility Curve-
Tech Benefit

"risk seeking"

(0, 1, 10, 100)





Weights

Audience Response Keypads

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Slide 18

Workgroup Analysis Framework

EDGEWOOD
Chemical Biological Center

The "3 Ps"

Technologies				Program Outcome Probability of Success: Minimal	Partial	Complete	Total Prob.	Technology Weight	Probability Adjusted Benefits
O2 Supply	Investment Level ($000)	Low	$5,000	0.85	0.13	0.02	1.00	3%	4.2
		Moderate	$10,000	0.65	0.30	0.05	1.00		8.7
		High	$15,000	0.45	0.40	0.15	1.00		19.5
			Technology Benefit	1	10	100			

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Slide 19

Workgroup Analysis Framework

Structure of Investment Areas & Levels

EQUITY for Windows - [c:\mydocu~1\other\equity\cpmast~1\cp_ap_03.eqw]

File Edit View Configure Clipboard Analysis Help

	1	2	3	4	5
O2Supply	None	Low	Mod	High	Maximum
CatOx	None	Low	Mod	High	Maximum
Regen	None	Low	Mod	High	Maximum
Single Pass	None	Low	Mod	High	Maximum
Aero Part Rem	None	Low	Mod	High	Maximum

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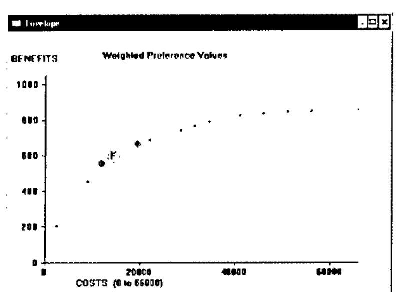
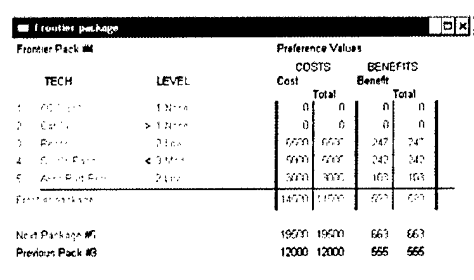
Slide 20

Workgroup Results



Pareto Diagram



Frontier Package

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Slide 21

Workgroup Results

Order of Buy

Order of Buy

Order of Buy

	TECH	LEVEL		COSTS INC	COSTS CUM	BENEFITS INC	BENEFITS CUM
#0	1 - O2Supply	1	None	0	0	0	0
#0	2 - CatOx	1	None	0	0	0	0
#0	3 Regen	1	None	0	0	0	0
#0	4 Single Pass	1	None	0	0	0	0
#0	5 - Aero Part Rem	1	None	0	0	0	0
#1	4 - Single Pass	2	Low	2500	2500	204	204
#2	3 - Regen	2	Low	6500	9000	247	452
#3	5 Aero Part Rem	2	Low	3000	12000	103	555
#4	4 - Single Pass	3	Mod	2500	14500	38	593

"Best-Value Package"

- Line 4
- Workgroup suggested for BAM to follow this investment strategy

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Slide 22

Lessons Learned

What did go well?	**What did not go well?**
•EQUITY™ led to a clear-cut solution to the funding strategy combinations	•DPL™ did not lead to a clear-cut decision for BAM (limited strategies)
•The BAM was provided with a rigorous examination of the COLPRO technology areas	•Working groups had to restructure the BAM's models (lack of standardized investment categories)
•An assessment of the funding strategies was accomplished by the BAM and the Working groups	•Working groups could not validate BAM's decisions

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